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Open File Report 6136

Precambrian Geology of the South Armstrong–Gull Bay Area, Nipigon Embayment, Northwestern Ontario

2004

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ONTARIO GEOLOGICAL SURVEY

Open File Report 6136

Precambrian Geology of the South Armstrong–Gull Bay Area, Nipigon Embayment, Northwestern Ontario

by

C.A. MacDonald

2004

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MISCELLANEOUS RELEASE—DATA 132

Geological and Lithogeochemical Data from the Northwest Nipigon Embayment, Lake Nipigon Region Geoscience Initiative (LNRGI); by C.A. MacDonald and E. Tremblay. This digital data release produced by the Ontario Geological Survey as part of the Lake Nipigon Region Geoscience Initiative (LNRGI) contains new geological and lithogeochemical data from the northwest Nipigon Embayment collected during the 2003 mapping season, and is being released in conjunction with OFR 6136. The geological data consists of lithologies, magnetic susceptibility measurements, as well as elevation and positional data for 624 stations visited. The x-y positional data are given in Universal Transverse Mercator (UTM) projection and grid system, Zone 16, North American Datum 1983. Selected photos are also presented for many of the outcrop stations. Available drill core data are also part of this release. The new analytical data are for 326 samples collected from the Nipigon diabase sills, the Archean basement rocks, and alkalic intrusions, and consist of specific gravity measurements, major oxide, trace element, and assay data. These data are organized in spreadsheets in Microsoft® Excel 97 (*.xls*) and in text files (*.txt*) on one CD-ROM.

This CD-ROM is available separately from the report.

Precambrian Geology of the South Armstrong–Gull Bay Area, Nipigon Embayment, Northwestern Ontario

C.A. MacDonald[1]
Ontario Geological Survey
Open File Report 6136
2004

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INTRODUCTION

The Lake Nipigon Region Geoscience Initiative (LNRGI) is a geoscience-based, geological data acquisition and compilation program operated by the Ontario Prospectors Association (OPA) and funded through an agreement with the Northern Ontario Heritage Fund Corporation (NOHFC). The LNRGI also includes partnerships with the private sector, Lakehead University and communities in the Lake Nipigon area. The major aim of the initiative is to attract interest from international and domestic investors to encourage new mineral exploration investment in high mineral potential areas in the region and adjacent areas; provide a framework for informed future land use decisions; and to contribute to a geological synthesis of the region. The initiative includes bedrock mapping projects, airborne magnetic and gamma-ray spectrometry surveys, ground gravity surveys, and targeted surficial geochemical and geochronological studies.

Bedrock mapping of the western Nipigon Embayment as part of the LNRGI began in June 2003 and will be completed over 2 years at a scale of 1:50 000. Mapping of the southwestern (Hart and MacDonald 2003; Hart and Magyarosi 2004a, 2004b; Hart and Préfontaine 2004a, 2004b) and southern (Hart, 2004 field season) areas of the Embayment will be completed by the Ontario Geological Survey (OGS) as part of its commitment of in-kind support to the LNRGI (Rayner, Lane and Easton 2003). Mapping of the northern (Hart and MacDonald 2003; MacDonald et al. 2004a, 2004b; Chart A, back pocket) and central (2004 field season) map areas is conducted under a contract agreement with the OPA (Rayner, Lane and Easton 2003).

This report includes the field observations and preliminary results of bedrock mapping conducted in 2003 in the northwestern part of the Nipigon Embayment (Figure 1) covering map sheets P.3536 and P.3537 (MacDonald et al. 2004a, 2004b, back pocket). Re-examination of diamond-drill core from several exploration holes in the area (courtesy of R. Middleton, East West Resource Corporation), combined with results of the airborne magnetic and radiometric surveys completed as part of the LNRGI (Ontario Geological Survey 2004a, 2004b, 2004c) greatly assisted with the geological interpretation. Lithogeochemical data and rock properties data collected during the 2003 field season are available separately from this report as Miscellaneous Release—Data 132 (MRD 132)(MacDonald and Tremblay 2004).

ACKNOWLEDGEMENTS

The author was assisted by senior assistants Mariska terMeer, Luc Lepage, Sonia Préfontaine and Jesse Hallé, and by junior assistants Chris Lane, Amanda Tremblay, Warren Graham, Eric von Bloedau, Roger Fournier and Kimberly Rowledge. Mr. Robert Middleton, East West Resource Corporation, allowed access to diamond-drill core from the Havoc, Norwood, and Mount Lake properties and provided background information for this map area and the Nipigon Embayment in general.

Mr. John Scott, Resource Geologist in the Ministry of Northern Development and Mines'Resident Geologist office, Thunder Bay, graciously gave 3 days of his time and use of a Ministry boat to help examine outcrops in the English Bay area of Lake Nipigon. The staff of the Thunder Bay Resident Geologist office also provided background information on previous geological studies and mineral occurrences. Their critical review of the maps prior to publication was greatly appreciated and improved the final versions of the maps.

Tom Hart provided logistical and technical support during the field season. Enrick Tremblay assisted with drafting of the maps and cross sections, as well as compiling and formatting data for MRD 132. Sara Jane McIlraith edited final drafts of the maps and the geodatabase.

The geophysics portion of this report is based on the new surveys completed as part of the LNRGI (Ontario Geological Survey 2004a, 2004b, 2004c) and was written by Desmond Rainsford[1].

Unless otherwise noted, all analytical work for this project was completed by the Geoscience Laboratories, Geoservices Centre, Sudbury.

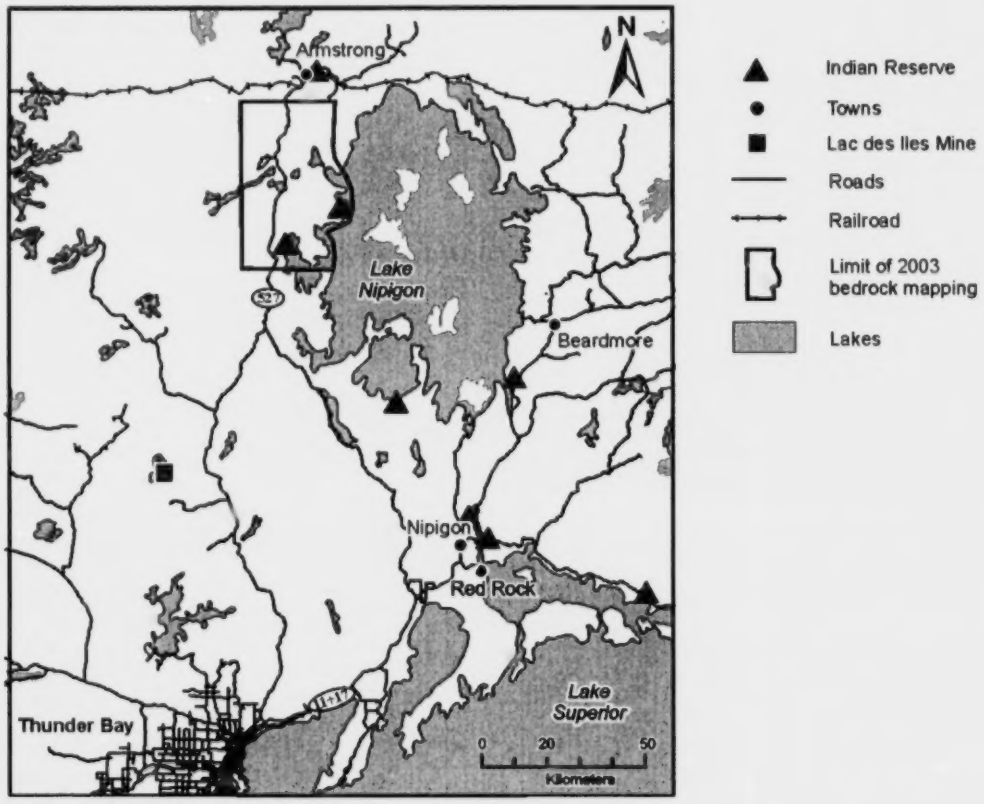

Figure 1. Key map showing the location of the south Armstrong–Gull Bay map area.

ACCESS AND PREVIOUS WORK

The south Armstrong–Gull Bay area, hereafter referred to as the map area, is located approximately 190 km north of Thunder Bay and is partially bordered by the shore of Lake Nipigon on its east margin (*see* Figure 1). Road access is provided by Highway 527 and some logging roads that extend east and west from the highway. Several lakes and rivers and the shore of Lake Nipigon also provide access to various parts of the map area. Thick tracts of blown-down forest (Photo 1) often hampered traverses by foot in the northern part of the map area. The eastern part of the map area is particularly scenic, with cliffs formed from the partially eroded Nipigon diabase sills (Photo 2). Topographic relief in the eastern

[1] Geophysicist, Precambrian Geoscience Section, Ontario Geological Survey, Sudbury.

part of the map area can be as much as 220 m but is typically 150 m. Changes in elevation in the western part of the map area rarely exceed 100 m.

Previous geological work in the western part of the north map area was conducted by Sage et al. (1974a, 1974b) at a scale of 1 inch to 2 miles (1:126 720). Sutcliffe (1986) completed geological investigations of the Nipigon diabase sills and the English Bay complex. Sutcliffe and Greenwood (1985a, 1985b) conducted bedrock mapping of the shore of Lake Nipigon and adjacent areas, at a scale of 1:50 000. The adjacent Obonga Lake area was mapped by Kustra (1967a, 1967b) at a scale of 1 inch to ¼ mile (1:15 840). Mineral exploration and prospecting in this area has been sparse, although areas along the west side of the map area were examined as part of mineral exploration of the Obonga greenstone belt. Corona Gold Corporation completed a diamond-drill program in 1998 for Olympic Dam-style copper-oxide-gold mineralization in the English Bay complex (Wood and Drost 1998). East West Resource Corporation is currently exploring the Havoc, Norwood and Pillar properties that are all located along a north trend through Waweig Lake, lying along an interpreted extension of the Black Sturgeon Lake fault (East West Resource Corporation 2003).

GEOLOGICAL SETTING

Rocks of both the Superior and Southern provinces are represented in the map area. The former includes Archean rocks of the volcanic-plutonic central Wabigoon Subprovince that disconformably underlie Mesoproterozoic sedimentary rocks and are intruded by Mesoproterozoic igneous rocks of the Southern Province. Several inliers of Archean rocks occur throughout the map area and consist dominantly of variably foliated to gneissic felsic to intermediate granitoids and mafic to felsic metavolcanic rocks. Mesoproterozoic pre-Keweenawan rocks in the map area include anorogenic igneous and associated metavolcanic rocks of the English Bay complex and sedimentary rocks of the Sibley Group that disconformably overlie and, in the case of English Bay, possibly intrude the Archean basement. Nipigon diabase sills intrude and overlie all previously noted rock types in the map area and are part of the 1.11 to 1.09 billion-year-old Midcontinent Rift-related Mesoproterozoic Keweenawan Supergroup (Blackburn et al. 1991; Sutcliffe 1991; Thurston 1991). More geological background information on the regional geology of the area is available in Sutcliffe (1991), Blackburn et al. (1991), and Thurston (1991).

PRESENT GEOLOGICAL SURVEY

Field work for the present geological survey (Project Number 03-304) took place from July to October 2003. A Hewlett-Packard IPAQ™ hand-held computer was used to collect the geological field data, which was later downloaded to ArcView® 8 from FieldWorker database software. A Garmin® 76S was used to acquire geographic positions for outcrops that were visited during the mapping. An average of no less than 50 readings, but typically 100 or more, was used to reduce error margins on the measurement. Error in x-y space was typically 5 to 7 m, with vertical error estimates around 15 to 20 m. Positions were recorded in Universal Transverse Mercator (UTM) co-ordinates using the North American Datum 1983 (NAD 83) (UTM Zone 16). Digital elevation data obtained from the Ontario Ministry of Natural Resources was compared to the recorded Global Positioning System (GPS) positional data as a check for aberrant records. A 1:20 000 scale digital map from the Ministry of Natural Resources Ontario Base Maps was used as the base for Maps P.3536 and P.3537 (*see* back pocket). The existing network of roads was updated on the base map.

General Geology

OVERVIEW

The total area mapped in 2003 covers approximately 1200 km^2 extending from just south of Gull River to approximately 10 km south of Armstrong (*see* Figure 1; Maps P.3536 and P.3537, back pocket). The western map boundary extends north through the western edge of Jackinnes Lake and Bukemiga Lake. The shore of Lake Nipigon (Figure 2) defines approximately two-thirds of the eastern boundary, south of Wabinosh Lake. As a result of the recent mapping, approximately 27% of the map area is composed of "new" geology with the identification of several previously undocumented Archean inliers, or "windows", which is a substantial increase in size from the 3 inliers previously mapped by Sage et al. (1974a, 1974b). The irregularly-shaped Archean inliers comprise about 25% of the map area and consist dominantly of variably foliated hornblende tonalite, biotite tonalite to granodiorite, gneiss and mafic to felsic metavolcanic rocks (*see* Figure 1; Table 1). Extension or continuation of these units has been interpreted in several areas (Maps P.3536 and P.3537, back pocket) based on compiled outcrops, subdued magnetic responses on aeromagnetic maps, and typically high radiometric responses in comparison to the adjacent Nipigon sills (MacDonald et al. 2004; Ontario Geological Survey 2004a, 2004b, 2004c). Mafic to felsic metavolcanic rocks may account for 45 to 50 km^2 of the Archean inliers in the map area and are exposed in outcrops located south and west of Jackinnes Lake and west of Cry Lake. These rocks have also been intersected in diamond drill core from the Vooges Lake area (Maps P.3536 and P.3537, back pocket). Continuation of these areas of predominantly mafic metavolcanic rocks have been interpreted southeast of Greske Lake, and further west of Cry Lake due to the subdued magnetic expression of these rocks on aeromagnetic maps and their similar low radiometric responses (Ontario Geological Survey 2004a, 2004b, 2004c). These areas may be correlative with units observed in the Obonga greenstone belt further to the west (Kustra 1967a, 1967b; Percival and Stott 2000).

A flat-lying succession of mafic metavolcanic pillowed to massive flows, pillow breccias, and interflow hyaloclastite breccia and hyaloclastite occur toward the north end of Pillar Lake (*see* Figure 2). Examination of outcrops from several locations would suggest that these flows have a thickness of 30 m and occupy an area of 25 km^2. The flat-lying and relatively undeformed nature of these flows, combined with the well-preserved nature of relatively delicate features such as hyaloclastite suggests that these rocks may be Proterozoic rather than Archean in age. Alternatively they could represent a previously unrecognized greenstone belt.

Exposures of Sibley Group clastic and chemical sedimentary rocks are rare in the map area and typically occur as small outcrops of limited areal extent. A combination of original Archean topography and the erosional level of the overlying diabase sills probably controls the distribution of the Sibley Group rocks.

The English Bay complex covers an area of approximately 80 to 85 km^2 and consists mainly of massive quartz and feldspar crystal tuffs with a variety of fragment types suggesting an extrusive, volcanic origin for most of the complex. At least one olivine gabbro sill intrudes the English Bay complex and has geochemical signatures similar to that of the Kitto peridotite intrusion (Hart 2003), located in Kitto Township on the east side of the Nipigon Embayment near Beardmore.

Nipigon diabase sills, consisting of northern sills with normal remnant magnetization and southern sills that are reversely polarized, intrude and typically overlie all other rock units in the map area.

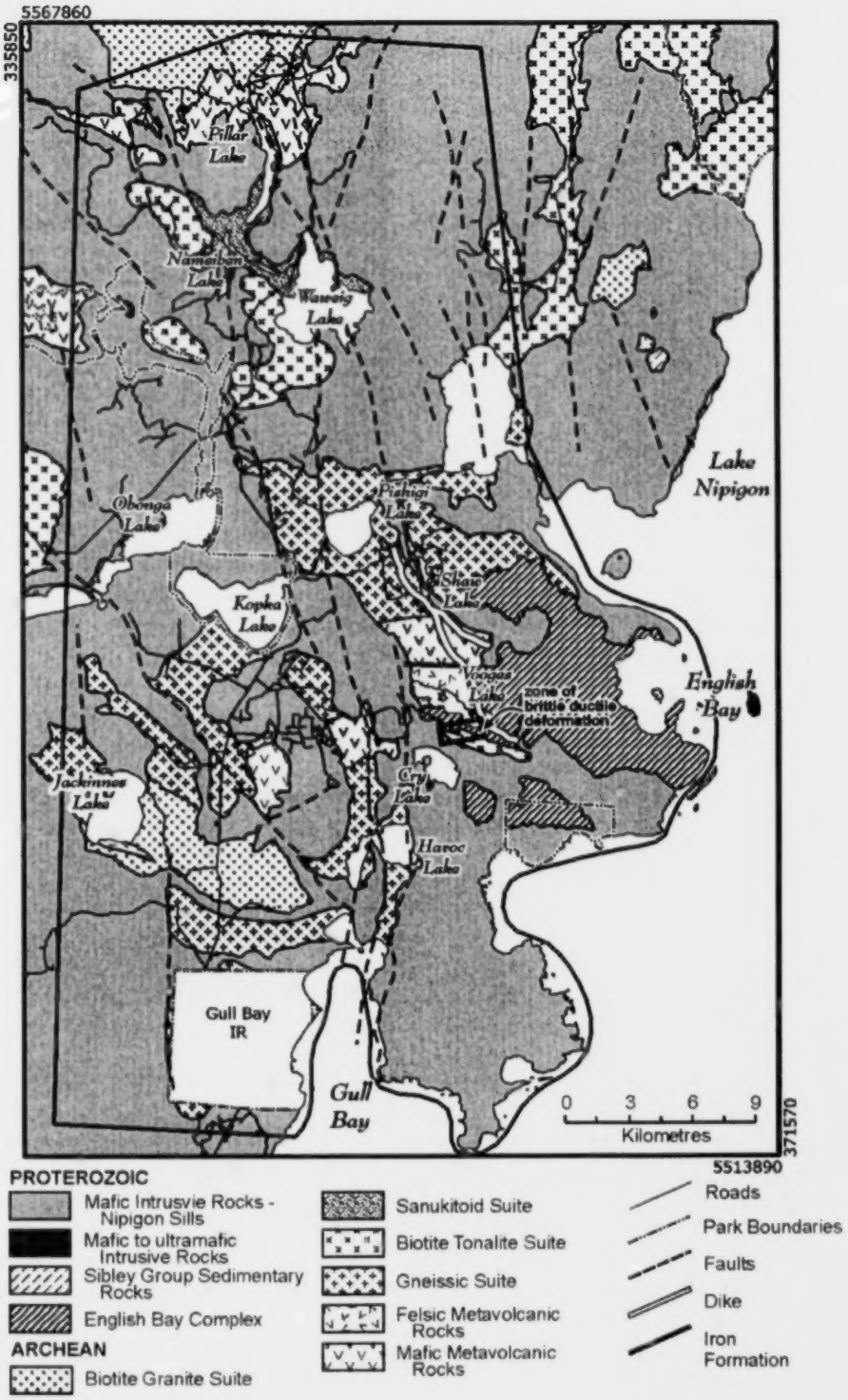

Figure 2. General geology of south Armstrong–Gull Bay area.

Table 1. Lithologic units in the south Arrmstrong–Gull Bay area.

PHANEROZOIC

Cenozoic

Quaternary

Recent: Stream and swamp deposits.

Pleistocene: Glacial deposits, sand, gravel, till.

unconformity

PRECAMBRIAN

Proterozoic

Mafic Intrusive Rocks: Nipigon Sills (1109 $^{+4}/_{-3}$ Ma[1])

Fine-, medium-, coarse-, and very coarse-grained diabase; magnetite-rich and/or coarse-grained diabase with intergranular magnetite; gabbro; very coarse-grained to coarse-grained amphibole-plagioclase±potassium feldspar[2]; inclusion-rich and inclusion-poor diabase chill margins; aplite or very fine-grained felsic phases of diabase.

intrusive contact

Mafic to Ultramafic Intrusive Rocks

Olivine melagabbro.

intrusive contact

Sibley Group

Rossport Formation: mudstone; siltstone; sandstone; carbonate breccia; debris flow.

Pass Lake Formation: conglomerate.

unconformity

English Bay Complex (1537 $^{+10}/_{-3}$ Ma[1])

Felsic crystal tuff to crystal lapilli tuff; crystal lithic lapilli tuff, fine tuff; pyroclastic breccia[3]; coarse-grained massive granitic-like crystal lapilli tuff and/or intrusive porphyry.

intrusive contact

Alkalic Intrusive Suite

Lamprophyre dikes; carbonate-bearing, xenolith-rich, mafic to alkalic dikes.

intrusive contact

Diabase Dikes: Fine- to medium-grained diabase.

intrusive contact

Archean

Biotite Granite Suite[4]

Unsubdivided; leucocratic to mesocratic; feldspar megacrystic; granodiorite to granite. Includes gneissic, massive, pegmatitic, and aplitic varieties.

intrusive contact

Sanukitoid Suite

Unsubdivided; monzonite to syenite; gabbro to diorite; and aplite.

intrusive contact

Biotite Tonalite Suite[4]

Unsubdivided; leucocratic to mesocratic; feldspar megacrystic; granodiorite to granite. Includes weakly gneissic varieties.

intrusive contact

Gneissic Suite[4]

Unsubdivided; felsic to intermediate granitoid gneiss.

intrusive contact

Syntectonic to Posttectonic Mafic Intrusive Rocks

Gabbro and melanocratic gabbro.

intrusive contact

Felsic Metavolcanic Rocks

Crystal lapilli tuff, crystal tuff, fine tuff.

Mafic Metavolcanic Rocks[5]

Massive and pillowed flows; pillow fragment or hyaloclastite breccias; tuff; lapilli tuff.

Notes: [1] Davis and Sutcliffe (1985). [2] This unit could represent a late magmatic phase of the sills or assimilation of Sibley Group sedimentary rocks, or a combination of both processes. [3] Interpreted by Sutcliffe (1986) as a volcanic conglomerate (debris flow). [4] Contacts between units 11, 12 and 15 may be gradational or obscure, especially in small outcrop. [5] Mafic metavolcanic rocks in the Pillar Lake area are of unknown age, and may be Proterozoic.

ARCHEAN

Metavolcanic Rocks

Mafic and felsic metavolcanic rocks are interpreted to underlie a 10 to 15 km^2 area north of Vooges Lake based on outcrops and diamond-drill core from 4 of the Havoc Property diamond-drill holes (Maps P.3536 and P.3537, in back pocket). The area immediately north of Vooges Lake is interpreted to be underlain by felsic to intermediate metavolcanic rocks based on core observed from a diamond-drill hole near the northwest shore of the lake. Diamond-drill hole Havoc 02-04 intersected 215 m of felsic to intermediate metavolcanic rocks consisting mainly of fine tuff to schist with local areas of silicification and quartz veining (East West Resource Corporation 2002). The area immediately north of this felsic to intermediate metavolcanic unit is underlain by dominantly mafic metavolcanic rocks based on diamond-drill core in hole Havoc 02-03. The contact between the felsic and mafic units is interpreted to be a continuation of a steeply north-dipping shear zone in mafic metavolcanic rocks observed in diamond-drill hole Havoc 02-03. If the felsic lithologies in Havoc 02-04 correlate with felsic metavolcanic rocks at the base of Havoc 02-03, then this would indicate south-side-up displacement along the north-dipping shear zone. Outcrops of strongly foliated to schistose mafic metavolcanic rocks occur west of Cry Lake and are similar to those described in diamond-drill hole Havoc 02-03.

The 60 to 75 m wide deformation zone noted in diamond-drill hole Havoc 02-03 could explain the west-trending, linear magnetic low observed on aeromagnetic maps of the area (Ontario Geological Survey 2004a, 2004b, 2004c) and the local occurrence of hematite. Percival and Stott (2000) also describe a similar northeast-trending ductile shear zone in the Obonga greenstone belt that occurs in similar, mafic metavolcanic-derived, chlorite schists. They suggest south-side-up displacement based on kinematic indicators.

Archean felsic metavolcanic rocks occur in 3 outcrops located south of Jackinnes Lake. These rocks are a moderately well-foliated and bedded sequence of quartz crystal tuff to fine tuff. Although not definitive, weak gradational contacts between the quartz crystal tuff and fine tuff may indicate a top direction to the south. Contact relationships between the felsic metavolcanic rocks and adjacent outcrops of foliated biotite granite to biotite granodiorite were not observed. An additional outcrop of fine-grained to aphanitic mafic metavolcanic rock containing hematite and chlorite alteration was found west of Jackinnes Lake. These units, combined with those observed in the Havoc Property diamond-drill core, may correlate with rocks of the Obonga greenstone belt (2855 to 2726 Ma; Tomlinson et al. 1998). In particular, they may be similar to units described from the Southern assemblage metavolcanic sequence by Percival and Stott (2000).

Several small outcrops of mafic metavolcanic rocks also occur on the northeast shore of Bukemiga Lake and southeast of Shaw Lake. Mafic and possibly felsic metavolcanic rocks are interpreted to underlie a 1 km^2 area west of Jackinnes Lake; a 5 km^2 area southeast of Greske Lake; a 5 km^2 area west of Cry Lake; the area north of Vooges Lake; and the areas surrounding Bukemiga and Vale lakes. Expansion of these interpreted areas beyond mapped outcrops is based on the LNRGI airborne magnetometer and spectrometer surveys (Ontario Geological Survey 2004a, 2004b, 2004c).

An apparently flat-lying succession of mafic metavolcanic rocks crops out near the north end of Pillar Lake. The unit extends over an approximately 20 to 25 km^2 area and consists of pillowed flow breccia, hyaloclastite breccia, pillowed and massive flows. Examination of outcrops from several locations would suggest that the apparently flat-lying unit has a thickness between 20 and 40 m. Lower portions consist of 3 or 4 alternating beds of pillowed flows with accompanying flow top breccia and or

pillow breccia and hyaloclastite overlain by a 1 to 2 m thick layer of massive flow and/or sill. Locally, this unit displays slightly flattened 10 cm to 1 m diameter pillows with interflow hyaloclastite (Photos 3 and 4). Concentric jointing and tortoise shell-like cracks are common. Alteration of this unit typically consists of weakly to moderately pervasive to moderate patchy hematite alteration and local weak to moderate patchy sericite alteration. Alteration intensity increases with proximity to the north tip of Pillar Lake and along a creek leading between Mundell and Pillar lakes. The flat-lying and relatively undeformed nature of these flows, combined with the well-preserved nature of relatively delicate primary features such as hyaloclastite may suggest that these rocks are Proterozoic rather than Archean. Alternatively they could represent a previously unrecognized greenstone belt. This unit has been sampled for U/Pb geochronology as part of the LNRGI geochronology project (Rayner, Lane and Easton 2003).

Oxide Facies Iron Formation

Although not exposed on surface, evidence of chemical metasedimentary rocks occurs within at least 3 of the Havoc Property diamond-drill holes. In diamond-drill hole Havoc 02-03, a 0.5 m wide zone of strongly hematized mafic metavolcanic rock is described with 0.5 cm bands of red jasper interspersed with red hematite laminae (East West Resource Corporation 2002). A larger zone of hematization within the same diamond-drill hole occurs over a 30 m interval at 59.5 to 90.5 m depth. The zone is described as strongly deformed mafic tuff with intense red hematite and quartz veins (East West Resource Corporation 2002). Although noted as relatively non-magnetic in hand samples this unit may correspond to a pronounced west-trending magnetic high north of Vooges Lake (Ontario Geological Survey 2004a, 2004b, 2004c). The west-trending magnetic feature appears to terminate at a north-trending diabase ridge and the inferred position of a possible splay off the Black Sturgeon fault (*see* Figure 2; Map P.3537, back pocket).

The hematite-rich zone in diamond-drill hole Havoc 02-03 may correlate with a similar 30 m interval in diamond-drill hole Havoc 02-01 described as maroon-gray tuffaceous iron formation with layers of white chert, jasper and specular and red hematite. If the two units correlate it would indicate at least 200 m of vertical displacement across the north-trending structure.

Alternatively, the magnetic feature and occurrence of hematite could be related to the 60 to 75 m wide deformation zone noted in diamond-drill hole Havoc 02-03. Specular and red hematite is also noted within felsic metavolcanic rocks in the Jackinnes Lake area and may be related to similar east- or north-trending structures in that area (*see* Figure 2; Maps P.3536 and P.3537, back pocket).

Syntectonic Mafic Intrusive Rocks

Two small (metre-scale) outcrops of weakly to nonfoliated gabbro to melagabbro occur on the northwest shore of Bukemiga Lake and west-northwest of Jackinnes Lake. They are typically located in close proximity to outcrops of mafic metavolcanics.

Felsic Intrusive Rocks

GNEISSIC SUITE

Rocks belonging to the gneissic suite are characterized by their strong foliation and typically heterogeneous-layered nature that is evident both on the outcrop and map scales (Photo 5). Overall composition of the gneissic suite is dominantly tonalite with local areas containing granodioritic to granitic or mafic compositions. Mafic layers, pods or discontinuous lenticles in the gniess are typically composed mainly of fine- to medium-grained amphibole. Layering in the gneissic suite may range from very thinly layered (<3 cm), as in outcrops on Pishigi Lake, to thickly (30 cm to 100 cm) or very thickly layered (1 to 3 m) as in outcrops in the Collins River Road and Havoc Lake area, respectively.

BIOTITE TONALITE SUITE

Rocks of the biotite tonalite suite are generally quite leucocratic with typically no more than 5 to 10% mafic minerals. Compositionally they range from leucocratic biotite tonalite to granodiorite with slightly more mafic and potassium feldspar megacrystic varieties locally. This suite varies from moderate to strongly foliated to locally gneissic, and locally may be gradational into rocks of the gneissic suite.

SANUKITOID SUITE

A multiphase, irregular-shaped intrusion occurs within the Pillar–Nameiban–Waweig Lakes area. Rock types comprising the intrusion range from melanogabbro to pyroxenite and/or amphibolite, gabbro to diorite, syenite to monzonite and quartz monzonite. Melanogabbro to pyroxenite is the least abundant lithology and is observed in only 1 outcrop on the east shore of Pillar Lake, where it occurs as medium to large subangular blocks within a later syenite to monzonite phase (Photo 6). Variably foliated gabbro to diorite forms the second most abundant lithology in the intrusion. It is also exposed only along the northeast shore of Pillar Lake and is composed mainly of plagioclase, amphibole and biotite with the sporadic occurrence of trace pyrite. Dikes of compositionally similar weakly to nonfoliated syenite to monzonite and a 2 to 5 m wide fine-grained intermediate dike locally crosscut the gabbro to diorite.

Dikes of red (hematized) syenite to monzonite that form the main phase of the intrusion crosscut the gabbro to diorite. Syenite to monzonite and quartz monzonite phases are characteristically massive, nonfoliated, medium- to coarse-grained and inequigranular, with less than 10% mafic minerals and typically less than 5% quartz. Local, less than 1 to 10 cm, irregularly shaped, feldspar-phyric mafic inclusions occur on the east shore of Pillar Lake near contacts with the more mafic phases. The inclusions typically appear partially "digested" by the syenite to monzonite and may be xenoliths of the above-mentioned gabbro (Photo 7). Local variations of the red granite include syenitic pegmatite dikes, aplite dikes, and medium-grained phases with 15 to 20% amphibole and biotite that is moderately to weakly foliated. Localized weak to moderate hematization of feldspars and moderate, vein- or fracture-controlled, earthy and specular hematite commonly occurs in outcrops along the east shore of Pillar Lake. Outcrops on Nameiben Lake and in the Collins River Road area are similar in character.

An outcrop on an island near the center of Waweig Lake consists of 2 main phases: a massive, medium-grained, magnetite-bearing syenite to syenogranite phase and a pegmatitic phase similar to dikes observed on Pillar Lake. A 2 to 3 m wide, fine-grained diabase dike, possibly related to the Nipigon sills, also crosscuts the pegmatitic phase on the island (Photo 8).

BIOTITE GRANITE SUITE

Rocks of the biotite granite suite are exposed in a large area north of Pillar Lake and as an irregular-shaped southeast-trending belt in the Jackinnes Lake area. It is typically leucocratic, pink to white, medium- to coarse-grained and weakly foliated. Sugary-textured aplite dikes are common as are local feldspar megacrystic and strongly foliated to gneissic varieties. This unit may contain xenoliths of the felsic metavolcanic rocks, sanukitoid, gneissic or biotite tonalite suite particularly with proximity to contact areas. Outcrops of this unit (or possibly the sanukitoid body in the Pillar–Nameiban Lakes area) may be similar to those occurring on the northern edge of the map area and on the "Red Granite property" of East West Resource (R. Middleton, Exploration Manager, East West Resource Corporation, personal communication, 2003).

PROTEROZOIC

Alkalic Intrusive Suite

Neoarchean to Paleoproterozoic carbonate-bearing dikes crosscut Archean mafic metavolcanic and gneissic rocks at 2 outcrops in the Shaw Lake area. The dikes appear discontinuous, ranging from less than 1 to 2 m wide, are moderately magnetic, and may contain a variety of phenocrysts and fragments. Matrix to the dikes consists of grey to dark grey, carbonate-rich, fine-grained to aphanitic material. Phenocryst mineralogy includes fine- to coarse-grained potassium feldspar, fine- to medium-grained amphibole, fine- to medium-grained magnetite, and possible fine-grained biotite. Fragments or xenoliths are typically subangular and reflect the host rock that the dike has intruded (Photo 9).

Sibley Group Sedimentary Rocks

Mesoproterozoic Sibley Group sedimentary rocks (Cheadle 1986) were observed at several locations in the north map area. Outcrops examined on Obonga and Vale lakes are typically found at the base of ridges where they are protected by overlying Nipigon diabase sills. Rock types range from less than 1 to 3 cm laminated to thinly bedded silty dolostone and sandstone, relatively uniform buff to cream-colored silty sandstone, and massive, well-sorted, medium-grained quartz arenite. East of Waweig Lake, Sibley Group outcrops consist of cyclical 2 to 3 cm interbedded buff sandy dolostone and red, recessive, muddy siltstone (Photo 10). These cyclic units overlie a conglomerate or regolith containing cobbles and pebbles of the underlying massive, hematized Archean granite to granodiorite. Locally, carbonate-bearing grey to grey-green laminated silty material has been observed to occur between the base of the cyclic units and the regolith or conglomerate. Some of this material may reflect input from a mafic source. A similar contact relationship between Sibley Group siltstones to sandstones and tropically weathered Archean granite or regolith is observed north of Roder Lake at the base of a diabase ridge.

In at least 3 areas, Sibley Group outcrops containing silty sandstone were found in association with the upper contact of the Pillar Lake mafic metavolcanic unit. The first, located on the west shore of Vale Lake, is in close proximity to the aforementioned mafic metavolcanic unit. Two other outcrops north of Chimney Lake and west of Pillar Lake contain discontinuous units of silty sandstone sandwiched between the upper mafic metavolcanic contact and the overlying Nipigon diabase sill. Another outcrop northwest of Pillar Lake may locally contain centimetre-size subangular to angular fragments of white to buff silty material in the flow top breccia of a pillowed flow. The occurrence of silty sandstone at the contact

between the flat-lying mafic flows and the overlying diabase may suggest that the the contact between the volcanic rocks and the Sibley Group is conformable.

Two outcrops of polymictic conglomerate were found to occur along strike with the Pillar Lake mafic metavolcanic unit. The first outcrop occurs on the east shore of McLauren Lake and is of limited areal extent. The second outcrop on the west end of Chimney Lake contains a large variety of clast types including pebble- to boulder-size subrounded to rounded clasts of medium-grained gabbro to melanogabbro; angular cobble- to boulder-size clasts of vesicular to amygdaloidal basalt; pebble- to cobble-size silty sandstone fragments; pebble- to cobble-size clasts of subrounded to rounded, pink to buff quartz arenite; and cobble-size subrounded to rounded felsic granitoid clasts (Photos 11 and 12). The conglomerate is very poorly sorted and can range from matrix- to clast-supported over several tens of metres. The matrix to this conglomerate is composed in part of fine- to very fine-grained sand size quartz grains and fine-grained medium grey-green material. The grey-green coloration suggests a mafic source for a large percentage of the matrix. More work is required to investigate the provenance and stratigraphic position of this enigmatic unit.

A small outcrop to subcrop of buff silty sandstone occurs along the north side of Vooges Lake Road just south of the center of Vooges Lake. The stratigraphic position of this outcrop with respect to the adjacent English Bay complex is unclear as no contact relationships were directly observed. However, the position and elevation of the sandstone outcrop near what may be the upper contact of a series of relatively flat-lying bedded volcaniclastic units of the English Bay complex may suggest a conformable contact. This would further support observations by Sutcliffe (1986) and Davis and Sutcliffe (1985) of porphyritic fragmental rocks (English Bay complex) that are interbedded with quartz arenite belonging to the lower formations of the Sibley Group.

English Bay Complex

The English Bay area was originally mapped by Sutcliffe and Greenwood (1985a) and was included as a part of Sutcliffe's (1986) PhD thesis. The English Bay complex covers about 80 km^2 and consists of 5 main rock types: 1) crystal tuff to crystal lapilli tuff; 2) fine tuff; 3) crystal lithic lapilli tuff; 4) massive crystal-rich tuff and/or intrusive porphyry; and 5) pyroclastic breccia (including the volcanic debris flows of Sutcliffe and Greenwood (1985a, 1985b) and Sutcliffe (1986)). The term English Bay complex, rather than English Bay intrusion or English Bay porphyry, is utilized in this report, because the body may be composed of intrusive as well as volcanic components (NACSN 1983). A more massive, coarse-grained, crystal-rich outcrop of the complex has yielded a U/Pb zircon age of $1537\ ^{+19}/_{-2}$ Ma (Davis and Sutcliffe 1985).

Fine tuff (Schmid 1981; Figure 1.11 in Easton and Johns 1986) is the least abundant rock type in the complex and occurs locally as less than 1 to 3 centimetre-wide discontinuous beds within crystal tuff to crystal lithic lapilli tuffs. In diamond-drill core most of these beds are fine to weakly crystal phyric and locally weakly laminated. Contacts between fine tuff and hosting crystal tuffs are typically sharp to locally gradational (Photos 13 and 15). Fine tuff also occurs as lapilli- to block-sized fragments within most other lithologies in the complex (Photos 14 and 17).

Crystal tuff to crystal lapilli tuff is volumetrically the most abundant rock type of the English Bay complex. It is typically massive with locally well-bedded areas as observed in outcrops on the south shore of Vooges Lake (Photo 15). Massive examples of this rock type typically contain 35 to 65% quartz and feldspar crystals in a fine-grained to aphanitic light red matrix. Quartz crystals are subhedral to subangular and commonly broken, range from less than 1 to 4 mm in diameter, and compose 20 to 35% of the rock. Quartz also displays a distinctive blue hue throughout most of the complex that is

presumably due to elevated TiO_2 contents (rutilated quartz). Feldspar crystals are also typically euhedral to subangular and broken, commonly segmented or broken along the crystal cleavage planes. Feldspar crystals typically compose 30 to 45% of the rock and range in size from less than 1 to 5 mm. Cognate and, to a lesser extent, accidental fragments occur sporadically, with their distribution possibly limited to specific geographic areas or stratigraphic intervals within the complex. Where lithic content increases, this rock type may grade into the crystal lithic lapilli tuff variety.

Crystal lithic lapilli tuffs are essentially the same as crystal lapilli tuffs with respect to crystal composition, content, size, and morphology, except for the presence of abundant lithic fragments (>10% lithic fragments). Lapilli to locally block-sized fragments may be juvenile, cognate or accidental in nature. Possible juvenile or cognate fragments observed include black to locally grey and green-grey, subround fragments with wispy laminations or layering reminiscent of flattened pumice tubes (Photos 16 and 17). Size of these fragments generally range from less than 1 to 4 cm. Occurrence of this fragment type appears to be limited to outcrops on several islands in English Bay as well as to certain intervals within the Corona diamond-drill core (particularly the upper, stratigraphically higher intervals). These fragments are similar to the pumiceous fragments described by Sutcliffe (1986).

Cognate fragments of lapilli- to block-size subrounded to subangular quartz-feldspar crystal tuff are also common, particularly in the Vooges Lake area (Photos 18 and 19). These fragments are similar in composition to the material in which it occurs and can typically be distinguished based on differences in crystal populations and alteration overprints. Other cognate fragments include lapilli-sized, subrounded to subangular, fine-grained aphyric to crystal-poor material (fine tuff). Sutcliffe (1986) also noted these fragments, or lapilli, as "inclusions of felsite, porphyry, flow banded and pumiceous fragments". One other type of possible cognate fragment occurs dominantly in English Bay diamond-drill hole EB-3. These fragments typically possess a characteristic "striped" appearance, are subrounded and range from less than 1 to greater than 10 cm in size (Photo 20). They are also generally highly affected by alteration overprints, with the overall colour of the fragments dependent on the alteration phase mineralogy. These fragments were originally logged as gneissic basement fragments (Wood and Drost 1999), but upon further inspection this fabric appears to be more of a primary feature than a metamorphic-induced mineral foliation. Examination of diamond-drill core from several other holes in the area showed that these fragments locally grade into pumice-like fragments with decreasing alteration intensity.

Accidental fragments of centimetre-sized, dark grey to grey-green, aphanitic material occur in this unit, and are possibly related to mafic metavolcanic rocks of the adjacent Obonga greenstone belt. Occurrence of this fragment lithology appears to be limited to the islands in English Bay and certain (lower) intervals in the Corona diamond-drill core. Subrounded to rounded quartz-rich fragments 2 to 5 cm in diameter also rarely occur mainly in outcrops on the islands of English Bay (Photo 21) and slightly more frequently in the upper sections of the diamond-drill core. These quartz-rich fragments could be a result of the incorporation of Archean (tonalitic?) basement during formation and deposition, or alternatively represent a quartz-rich fragment of the Sibley Group.

Massive, coarse-grained, crystal-rich or "granitic-textured" versions of the English Bay complex occur mainly within diamond-drill core and possibly 1 outcrop south of English Bay and west-southwest of Jackfish Island. This rock type is massive, brick red, and characterized by the presence of large subhedral to euhedral feldspar crystals (2 mm to 1.5 cm in diameter) that are commonly zoned (Photo 22). Quartz crystals are typically subhedral and 2 mm to 1 cm in size with the same distinctive blue tint observed in other units. Overall crystal content ranges from about 45 to 70%. When the crystal content increases to as much as 65% the unit begins to look particularly "granitic". However, weakly gradational contacts with adjacent crystal tuffs, and weak local variations in crystal size and content over 5 to 50 cm intervals may suggest the presence of poorly-developed bedding or layering.

The occurrence of cognate and possible juvenile fragments, and their limitation to specific geographic and/or stratigraphic intervals would imply a volcanic provenance for most of the complex. The "massive granitic textured " unit could represent a subvolcanic intrusion intruding into its own volcanic pile or alternatively it could represent the remnants of a rhyolite dome or similar tabular lava-like body.

Mafic to Ultramafic Intrusive Rocks

Rocks of the mafic to ultramafic suite occur in only 3 locations in the map area: as a sill within the English Bay diamond-drill core (holes EB-4 and EB-5); in outcrops mapped by Sutcliffe and Greenwood (1985a) on Birch Island west of English Bay; and on the west side of Jackfish Island. The rocks typically consist of medium-grained varieties of olivine gabbro. No ultramafic rocks were observed within the map area. Outcrops from Birch Island were sampled for future petrographic and geochemical comparisons to the sills observed in the English Bay diamond-drill core.

Nipigon Diabase Sill Complex

Nipigon diabase sills intrude and overlie 70% of the map area. Davis and Sutcliffe (1985) reported a U/Pb age of 1109 $^{+4}/_{-2}$ Ma from baddeleyite and zircon obtained from 2 sills in the Nipigon Embayment. This age is similar to that of the Osler Group volcanic rocks which are part of the Keweenawan Supergroup of the Miscontinent Rift. The Nipigon sills are generally brown to grey-brown, massive to medium-grained, equigranular- to intergranular-textured and gabbroic in composition. Local variations include fine- and coarse-grained with medium- to coarse-grained varieties commonly displaying ophitic and poikilitic textures. Rare outcrops of recessively weathering, massive, coarse- to very coarse-grained oikocrystic diabase occur in the Collins River Road area (Photo 23). A magnetite-rich phase also occurs containing greater than 5% intergranular to locally glomeroporphyritic magnetite in medium- to coarse-grained examples (Photo 24). Coarse-grained pods, veins or monzogabbroic versions also occur within the diabase (Photo 25) and could represent a late magmatic phase of the sills or assimilation of Sibley Group sedimentary rocks, or a combination of the 2 processes (Hart and Magyrosi 2004a). Sutcliffe (1986) subdivided the sills into ideal textural-mineralogical stratigraphic sections, but this "ideal" section is rarely observed in the north map area perhaps due to incomplete exposure.

Alteration

With the exception of the English Bay area, hematite alteration in the map area appears to be localized along a possible north-trending structure that extends from the southwest tip of Jackinnes Lake to north of Pillar Lake. The hematization event affects several of the rock units including the red granite, mafic metavolcanic sequence north of Pillar Lake, and the felsic metavolcanic rocks south of Jackinnes Lake. In the red granite the earthy variety of hematite occurs as local weak- to moderate-intensity dissemination through the rock and as fracture- or vein-controlled earthy and specular hematite. The flat-lying mafic metavolcanic unit typically displays weak sericite and weak- to moderate-intensity patchy hematite alteration particularly within the interpillow hyaloclastite and flow-top breccia units. Alteration intensity appears to increase with proximity to the inferred structure. The felsic metavolcanic rocks south of Jackinnes Lake are weak to moderately pervasively sericitized and overprinted by a similar patchy to pervasive and fracture-controlled hematization event.

The English Bay complex displays several episodes of alteration with complex, sometimes mutually crosscutting relationships. Most of the complex is characterized by pervasive, even, brick red coloration in the groundmass or matrix. This is due to a fine dusting of oxidized hematite in the matrix and/or groundmass and is possibly a primary feature of the rock.

Types of alteration within the English Bay complex include:

1. Strong patchy red hematite alteration affects all units within the English Bay complex. In these patches of strong red hematite alteration the feldspars are nearly destroyed or are difficult to distinguish from the adjacent red groundmass. Contacts of the alteration zones with the host rock are diffuse. The timing of this alteration event with respect to the other types listed below is unclear.
2. Multiple stages of mauve to purple (unoxidized hematite?) hematization. This alteration occurs as a) purple patches with diffuse boundaries, b) purple halos around veins, c) as specular vein and/or fracture infillings, and d) preferential or selective alteration of a bed or beds (e.g., as seen in the outcrop south of Vooges Lake; *see* Photo 15).
3. Multiple episodes of sericite alteration: a) vein- and/or fracture–controlled halos, b) selective alteration of fine-grained, crystal poor and/or recessive weathering beds, and c) as moderate to strong feldspar-destructive alteration (sericite), which may locally be pervasive.
4. Vein-controlled epidote alteration. This alteration may occur with quartz, and rarely with specular hematite and/or purple fluorite.

Structural Geology

Evidence for at least 2 major shear zones exists in the Archean rocks of the map area. The first is an apparently east-trending (based on geophysical surveys), subvertical zone of brittle-ductile deformation found in mafic metavolcanic rocks in diamond-drill hole Havoc 02-03. Although not exposed on surface, the fault juxtaposes a dominantly mafic metavolcanic package to the north with a felsic metavolcanic package to the south (*see* Figure 2; Map P.3537, back pocket). Percival and Stott (2000) also describe a similar northeast-trending ductile shear zone in the Obonga greenstone belt that occurs in similar mafic metavolcanic-derived chlorite schists. They suggest south-side-up displacement based on kinematic indicators. The second area is a 200 to 500 m wide zone of brittle ductile deformation observed in a series of outcrops along the Vooges Lake Road and west of Kettle Lake. The intensely developed east- to northeast-trending fabric ranges in intensity from strongly foliated to gneissic and locally mylonitic. In strongly foliated to protomylonitic rocks the fabric is defined by alignment of mafic minerals, ribbon quartz and feldspar augen (Photo 26). Mylonitic to gneissic rocks exhibit grain size reduction and separation into compositional bands. Kinematic indicators such as sigmoidal and delta feldspar porphyroclasts (Photo 27) are unclear as to the direction of lateral offset.

Fabric development in other Archean inliers in the map area generally consist of weak- to moderate-intensity, east- to northeast-trending mineral foliations that correlate well with regional trends in the central Wabigoon Subprovince.

A series of northwest- and north-trending faults are prominent in the map area (*see* Figure 2; Maps P.3536 and P.3537, back pocket). Northwest-trending faults appear to correlate with structures in the central Wabigoon Subprovince and may control the location of Archean inliers. A series of subparallel north-trending faults, which include the Black Sturgeon fault, may represent the failed arm of the Keweenawan Midcontinent Rift (Sutcliffe 1991).

The hematite-rich zone in diamond-drill hole Havoc 02-03 may correlate with a similar 30 m interval in diamond-drill hole Havoc 02-01 described as maroon-grey, tuffaceous iron formation with layers of white chert, jasper and specular and red hematite. The drill holes are on opposite sides of these north-trending structures that are inferred extensions of the Black Sturgeon fault (Map P.3537 and Chart A, back pocket). If the 2 units are correlative it would indicate at least 200 m of vertical displacement across the north-trending structure.

Varied amounts of vertical displacement are also evident between Sibley Group outcrops in the Shaw Lake area and diamond-drill hole Havoc 02-05. Three outcrops of Sibley siltstone to sandstone occur along the base of a southeast-trending diabase ridge in the Shaw Lake area. The contact between the Archean basement granitoids and the overlying sedimentary rocks was observed at one of these locations at a topographic elevation of 358 m. Outcrops of Archean basement rocks are also found in close proximity (within 60 to 100 m) to the other 2 Sibley Group outcrops, indicating that the contact between the 2 units is also between 350 to 370 m elevation. Diamond-drill hole Havoc 02-05 is located 4.2 and 5.5 km west and west-southwest of the Sibley Group outcrops, which also occur on the opposite side of 2 interpreted north-trending faults (Maps P.3536 and P.3537; Chart A, back pocket). The contact between Archean basement rocks and the overlying Sibley Group in diamond-drill hole Havoc 02-05 is not observed. However, observations by R. Middleton of East West Resource Corporation (personal communication, 2004) suggest that Sibley Group conglomerate near the base of this drill hole (at 314 m depth) is typical of conglomerate in other parts of the Nipigon Embayment found proximal to a contact with Archean granitoid rocks. If the contact were to occur near 325 m depth in the diamond-drill hole, meaning at a maximum of 90 m topographic elevation, then the vertical offset along one or both of the two interpreted north-trending structures would be a minimum of 260 m.

Vertical offset along at least one of these north-trending structures is also evident in the Waweig–Norwood Lakes area. The contact between Archean basement granites and Sibley Group sedimentary rocks east of Waweig Lake is found at 380 m topographic elevation. A similar contact between Archean granitic gneisses and overlying Sibley Group rocks is found in diamond-drill hole NW-02-01 at a depth of 347 m, equating to a topographic elevation of about 0 m because NW-02-01 was collared at 348 m elevation. This indicates approximately 380 m of vertical offset along one of the interpreted north-trending structures between Norwood and Waweig Lakes.

Similar vertical offset may also occur in the area between diamond-drill hole MT-01 and the Jackinnes Lake–Gull Bay area. Diamond-drill hole MT-01 is collared at an elevation of 315 m and contains the Archean basement–Sibley Group contact at a depth of 228 m (or 87 m topographic elevation). Although this contact is not observed in the Jackinnes Lake area, outcrops of Archean basement rocks are present at elevations ranging from 300 to 350 m. This would suggest the presence of another north- or possibly northwest-trending brittle structure with vertical offset possibly greater than 263 m. Outcrops of biotite granite and gneissic suite rock northwest of Duck Bay and southeast of Havoc Lake occur at maximum elevations of 310 to 320 m. This would also indicate vertical offsets of greater than 200 m along these north-trending structures.

Because of the flat-lying character of many Proterozoic rock units in the map area, and the evidence for displacements of 200 m or more across some faults in the map area, a few geological cross sections were prepared to illustrate the geology of the map area (Chart A, back pocket). The location of these cross sections was in part tied to the location of diamond-drill holes within the map area, in order to provide some constraints on the third-dimension.

In addition to the typical columnar jointing pattern observed in most diabase cliffs of the Nipigon Embayment (Photo 2), diabase outcrops in this area of the embayment also commonly display a relatively

evenly spaced horizontal to subhorizontal jointing pattern (*see* Photos 23 and 28). This jointing pattern, if related to cooling of the sills, may suggest orientation of the sills at time of emplacement.

Two joint sets of moderate to strong intensity were also noted in rocks of the English Bay complex along the northwest shore of English Bay. The joints are typically closely spaced in the order of 2 to 10 cm and are oriented at approximately 020° and 120° (Photo 29). Locally, this jointing pattern may appear arcuate or concentric.

Geophysical and Rock Property Data

A 49 693 km airborne magnetometer and gamma-ray spectrometer survey was flown over an area bordering the western shore of Lake Nipigon during the summer of 2003 (Ontario Geological Survey 2004a, 2004b, 2004c). This high-resolution airborne survey was flown 100 m above ground level, using a 150 m flight-line separation and covered all but the northern margin of the south Armstrong–Gull Bay map area. A program of ground gravity surveying to supplement the existing sparse network of gravity stations was also commenced and is on-going at the time this report was published. The results of the gravity survey are expected to be released in the summer of 2004.

In order to assist in the interpretation of the geophysics, rock physical properties, comprising magnetic susceptibility and specific gravity measurements, were recorded as part of the bedrock mapping effort. A total of 660 magnetic susceptibility measurements were obtained from outcrop using handheld KT-9 instruments. Specific gravity measurements of 301 surface and drill core samples were made in the laboratory.

The results of the aeromagnetic and gamma-ray spectrometer surveys were used to aid in the interpretation of the geology of the map area and in the refinement of the location of geological contacts, particularly in areas where there is little outcrop. This section of the report discusses the rock property results and describes the geophysical characteristics of major rock types in the area and how the geology can be inferred from images of the airborne magnetic and radiometric data. This section of the report was written by D. Rainsford, a geophysicist with the Ontario Geological Survey, Sudbury.

MAGNETIC SUSCEPTIBILITY

A minimum of 10 magnetic susceptibility measurements was collected on each outcrop visited during the mapping effort. Where the outcrop contained more than one rock type, a set of magnetic susceptibility measurements was collected for each. An average and a standard deviation were calculated for each set of 10 readings. The calculated mean is used as the representative value for the set of measurements and the standard deviation is used to assess the variability of the readings. From the 660 magnetic susceptibility observations, it was possible to assess the magnetic properties of 9 major rock units in the mapping area. The number of observations made for each rock type reflects its relative abundance in outcrop. Thus, Nipigon sill rocks have a large number of measurements (469); whereas, scarcely observed felsic metavolcanic rocks have only a few magnetic susceptibility readings (3). Other rock types that have only one or two observations were not included in this analysis. Averaged magnetic susceptibilities are listed in Table 2.

As the range and distribution of values for a single rock type can be quite varied, the mean may not be the best representation of magnetic susceptibility and so it is also useful to examine histograms of the data (Figures 3, 4 and 5). It is apparent that most of the major rock units have relatively low magnetic susceptibilities ($<10 \times 10^{-3}$SI) with the exception of the sanukitoid suite intrusive rocks and samples

belonging to the Nipigon sills. As a result, these low magnetic susceptibility rocks are not likely to be easily distinguished by their magnetic responses. Both the Nipigon sill and the sanukitoid suite rocks demonstrate distinctly elevated magnetic susceptibilities, which suggest that they can be identified by their magnetic signatures. In the case of the sanukitoid suite rocks, the range of values is large and probably reflects the multi-phase nature of the sanukitoid intrusions. The Nipigon sill rocks also have a large range, but the distribution of readings (*see* Figure 5) suggests a single population.

Table 2. Average magnetic susceptibilities of major rock units in the south Armstrong–Gull Bay area.

Rock type	Map unit	Mean magnetic susceptibility ($x10^{-3}$ SI)	Number of samples
Mafic metavolcanic rocks	2	9.51	29
Felsic metavolcanic rocks	4	0.15	3
Gneissic suite	11	5.77	37
Biotite tonalite suite	12	8.54	30
Sanukitoid suite	14	31.75	21
Biotite granite suite	15	0.73	18
Quartz-feldspar porphyry (English Bay complex)	27f	0.86	32
Sibley Group sedimentary rocks	28	7.69	9
Nipigon sill	31	24.58	469

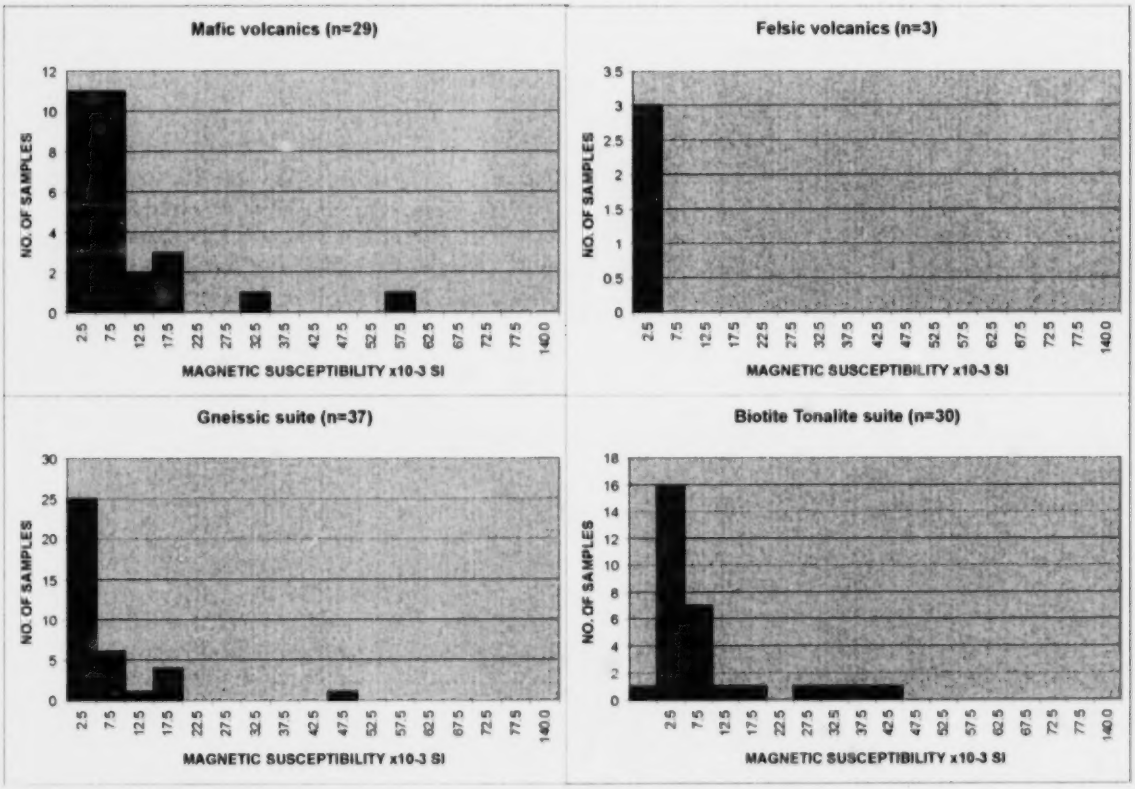

Figure 3. Histograms of magnetic susceptibilities for mafic and felsic metavolcanic rocks, and gneissic and biotite tonalite suite rocks.

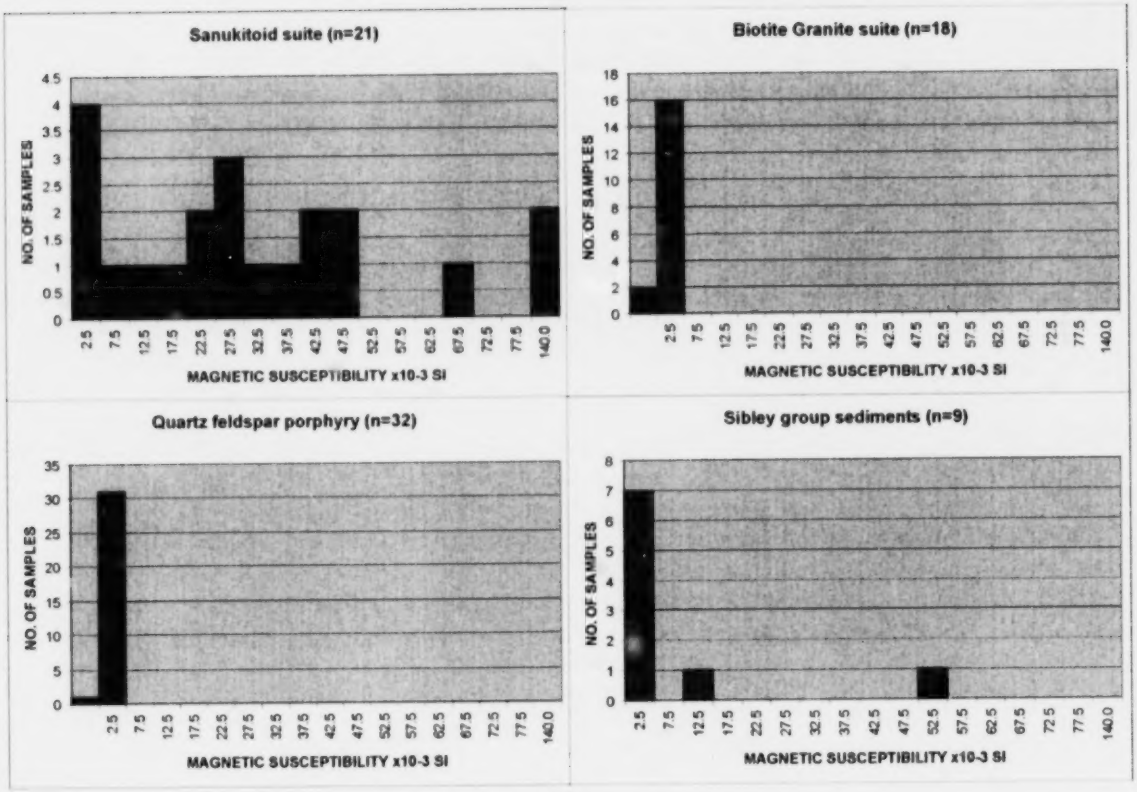

Figure 4. Histograms of magnetic susceptibilities for sanukitoid and biotite granite suite rocks, quartz feldspar porphyry of the English Bay complex, and Sibley group sedimentary rocks.

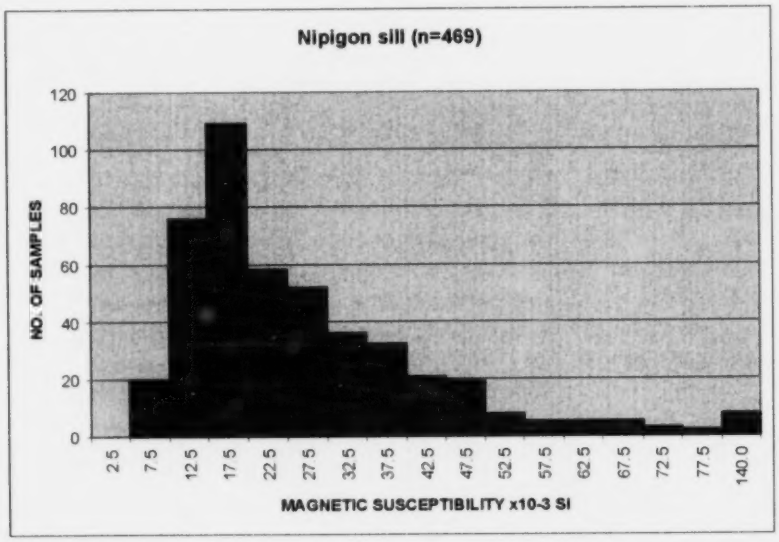

Figure 5. Histogram of magnetic susceptibilities for Nipigon sills.

SPECIFIC GRAVITY

Specific gravity measurements of specimens submitted for geochemical analysis were made in the laboratory by measuring their weight in air and in water. The rock density values will be useful in assessing the gravity data that is being collected in the area. The mean densities for the 295 samples measured are presented in Table 3. The results of an additional 6 samples are not included as either too few measurements were made from the same rock type to be meaningful, or a value was considered to be invalid.

As expected, the more felsic rocks (i.e., felsic metavolcanic rocks and quartz feldspar porphyry) exhibit the lowest densities and the more mafic rocks (i.e., mafic metavolcanic rocks, Nipigon sills) have the highest densities. As with the magnetic susceptibility data, the sanukitoid suite rocks show the greatest variability. The specific gravity of the Sibley sediments is surprisingly high, but is only represented by 4 samples; consequently, the utility of this value is questionable.

Table 3. Average specific gravity for major rock units in the south Armstrong–Gull Bay area.

Rock type	Map unit	Mean specific gravity (g/cm^3)	Number of samples
Mafic metavolcanic rocks	2	2.85	29
Felsic metavolcanic rocks	4	2.66	8
Sanukitoid suite	14	2.68	7
Quartz-feldspar porphyry (English Bay complex)	27	2.58	34
Sibley group sedimentary rocks	28	2.84	4
Nipigon sills	31	2.98	213

AIRBORNE GEOPHYSICAL SURVEYS

The results from the airborne magnetic and gamma-ray spectrometer survey are published both in paper form (Ontario Geological Survey 2004a, 2004b) and digitally (Ontario Geological Survey 2004c). The digital publication contains a detailed report describing the survey parameters, logistics and processing. The data from these surveys have been used to assist with the compilation of the geological map. In particular, the airborne geophysics were used to define major structures, refine contacts in areas of sparse outcrop and infer geological units in areas of no exposure. The following section reviews how the presence of some rock units can be determined from their characteristic airborne geophysical responses.

The predominant rock type in the area, and the one with the most easily recognised geophysical signature, are the Nipigon sills. These gabbroic rocks, in addition to having high magnetic susceptibility, are low in radiogenic elements (Figure 6d), as is generally the case with mafic rocks. Furthermore, Nipigon sill rocks exhibit a distinctive magnetic texture that is particularly evident in shaded residual field and second vertical derivative images (Figures 6b and 6c). These images in Figure 6, from the Pike Bay peninsula area, show a complex network of linear and sinuous anomalies in the shaded magnetics (*see* Figure 6b) and a very intricate pattern of short wavelength features bounded by strong edge anomalies in the second vertical derivative data (*see* Figure 6c).

In comparison to the Nipigon sill rocks, Archean basement rocks have a subdued magnetic expression. This is in agreement with the low magnetic susceptibility values measured for basement rocks (*see* Table 2). Figure 7b shows the typically smooth and slowly varying magnetic character of the basement rocks, in sharp contrast to the highly perturbed pattern of adjacent Nipigon sills. The magnetic second vertical derivative expression (Figure 7c) is also similarly subdued. Two north-trending, reversely polarized dikes are evident in the magnetic pattern of the Archean rocks. As there is little contrast in the

magnetic properties of the basement rocks in the area, it is generally not possible to distinguish between them using magnetic patterns. Depending on the composition of the basement rocks, however, the radiometric response generally tends to be significantly higher than that of the Nipigon sills. For example, the potassium response, shown in Figure 7d, is elevated in the southern and eastern parts of a basement window, but is probably compromised in part by surface conditions (transported overburden, swampy ground).

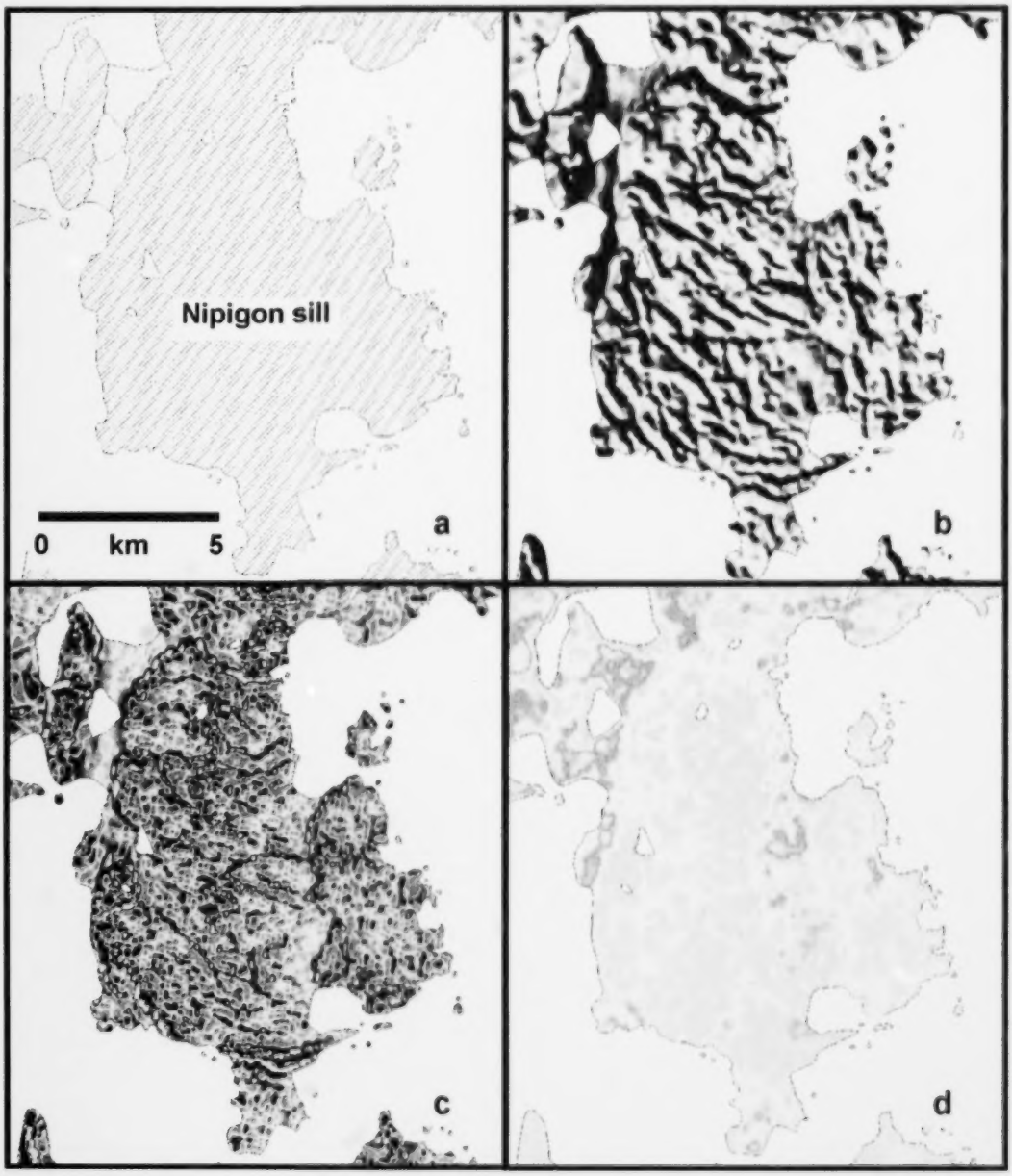

Figure 6. Airborne geophysical responses from a Nipigon sill in the Pike Bay peninsula area. The surface extent of the sill is shown in image **a**. The residual magnetic field pattern, shaded from the northeast, is in image **b**. The magnetic second vertical derivative map is shown in image **c**. Potassium response is displayed in image **d** , with the the light tones representing low values.

A large sub-circular feature is seen in the magnetic pattern near the northern limit of the map area (Figure 8b). The feature is about 10 km in diameter and is expressed by an arcuate positive anomaly to the west and an arcuate negative anomaly to the east. The fact that it has little expression in the magnetic second vertical derivative data (Figure 8d), and does not correlate with geological boundaries mapped at surface, suggests that the feature may be deep-seated. The presence of mafic metavolcanic rocks (not seen elsewhere in the area) around the northwest quadrant of this feature suggests that it might be the magnetic expression of a volcanic centre.

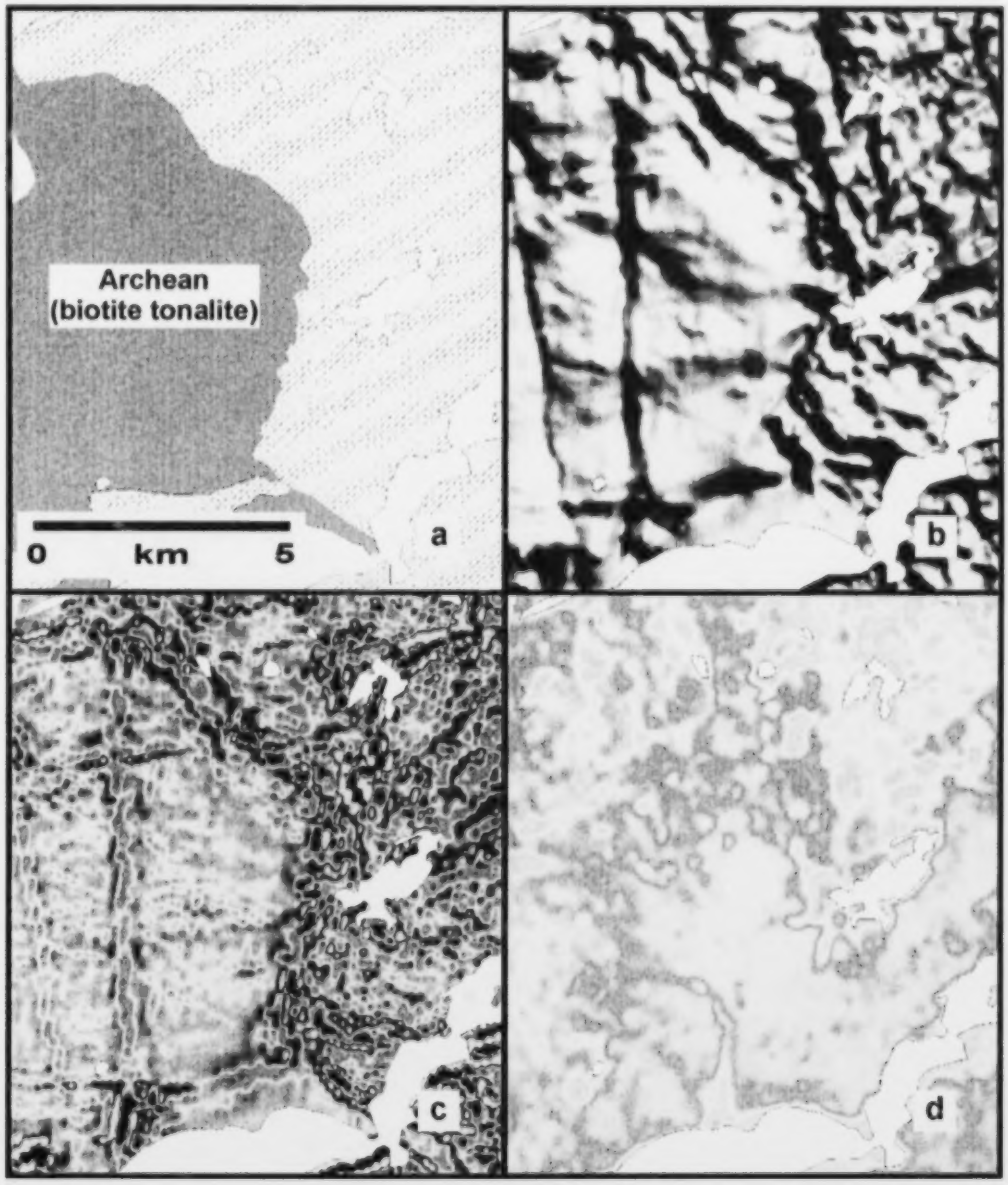

Figure 7. Airborne geophysical responses from the eastern Obonga Lake area. The outline of an Archean biotite-tonalite intrusion is shown in image **a**. The residual magnetic field pattern, shaded from the northeast, is shown in image **b**. The magnetic second vertical derivative map is shown in image **c**. Potassium response is displayed in image **d**, with the light tones representing low values.

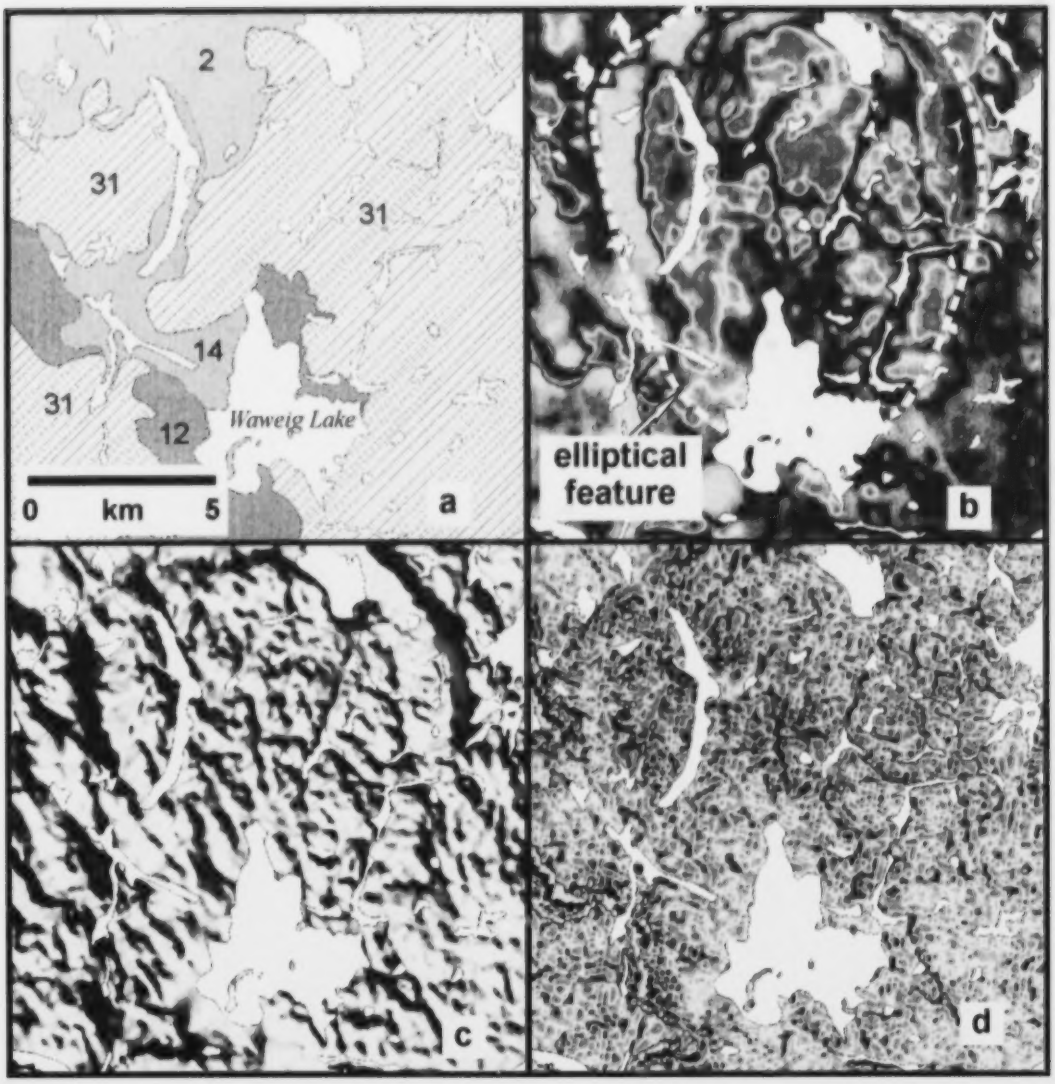

Figure 8. Airborne geophysical responses from the Waweig Lake area. The surface geology shown in image **a** is coded as follows: 2 – mafic metavolcanic rocks, 12 - biotite-tonalite suite rocks, 14 - sanukitoid suite rocks, 31 - Nipigon sill. The residual magnetic field is shown in image **b**. The residual magnetic field shaded from the northeast is shown in image **c**. The magnetic second vertical derivative map is shown in image **d**.

Recommendations for Exploration

All geochemical samples collected as part of this study (MacDonald and Tremblay 2004) were analyzed for Au, Pt and Pd. In addition, selected samples from the map area were submitted for assay; these results are also included in MacDonald and Tremblay (2004).

Previously undocumented areas of mafic and felsic metavolcanic rocks, possibly related to the Obonga greenstone belt, occur in several parts of the map area. These areas may hold potential for Pb-Cu-Zn volcanogenic massive sulphide (VMS) deposits and should be investigated further. Additionally, 2 areas of brittle-ductile deformation, noted in the Vooges Lake area, may hold potential for shear zone-hosted gold deposits. In particular, the presence of highly strained felsic and mafic metavolcanic rocks in diamond-drill hole Havoc 02-03 with associated sericite and silicification, as well as the presence of quartz-tourmaline veins and trace pyrite (East West Resource Corporation 2002), would warrant further investigation in other parts of the map area. The potential also exists in these greenstone belt inliers for Archean mafic to ultramafic bodies similar to the Core Zone mafic intrusion, Awkward Lake gabbro, and the Cr-Ni-Cu-platinum group element mineralized Puddy Lake serpentinite body (Schnieders et al. 2002).

The multiphase intrusion in the Pillar–Nameiban–Waweig Lakes area may belong to the Archean sanukitoid suite and thus the mafic to ultramafic portions of this intrusion should be investigated for their platinum group element potential. Gabbroic to pyroxenitic rocks with disseminated chalcopyrite, pyrrhotite and pyrite from sanukitoid intrusions such as the Roaring River Complex have returned assays up to 2.1 g/t Pt+Pd+Au (Schnieders et al. 2002).

Platinum group element mineralization in mafic rocks of the Nipigon Embayment is typically hosted within the mafic to ultramafic suite rocks, such as the Seagull and the Disraeli intrusions. Although these types of intrusions are only exposed in the English Bay portion of the map area and are of limited extent, several authors (e.g., Middleton 2001) have suggested that their occurrence may be related to the north-trending Black Sturgeon graben or rift structure. If this is true, then the portions of the map area adjacent to many of the north-trending structures in the map area that are interpreted to be extensions and/or splays off the Black Sturgeon fault may be good exploration targets.

Several areas within the Nipigon Embayment may have potential to host iron oxide-copper-gold (i.e., Olympic Dam type) deposits. In particular the English Bay complex has many of the same features that characterize the deposit type, including the presence of a body (1.54 Ga: Davis and Sutcliffe 1985) of anorogenic granite composition, with locally moderate to strong hematite, sericite and silica alteration, as well as elevated zirconium, yttrium and rare earth element contents (Sutcliffe 1991; Schnieders et al. 2002).

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Photo 1. Warning sign posted along Highway 527 indicating area of forest blow down.

Photo 2. Columnar and horizontal jointing in diabase cliffs. East shore of Pillar Lake.

Photo 3. Close-up shot showing interpillow hyaloclastite, Pillar Lake area. Station 1100; UTM 346629E, 5563694N, Zone 16. Scale card is 8.5 cm long.

Photo 4. Pillowed mafic volcanic flows, Pillar Lake area. Station 1100; UTM 346629E, 5563694N, Zone 16.

Photo 5. Basement gneisses of the Wabigoon subprovince. Northwest Shaw Lake area. Station 3010; UTM 354166E, 5542425N; Zone 16. Pen is 15 cm long.

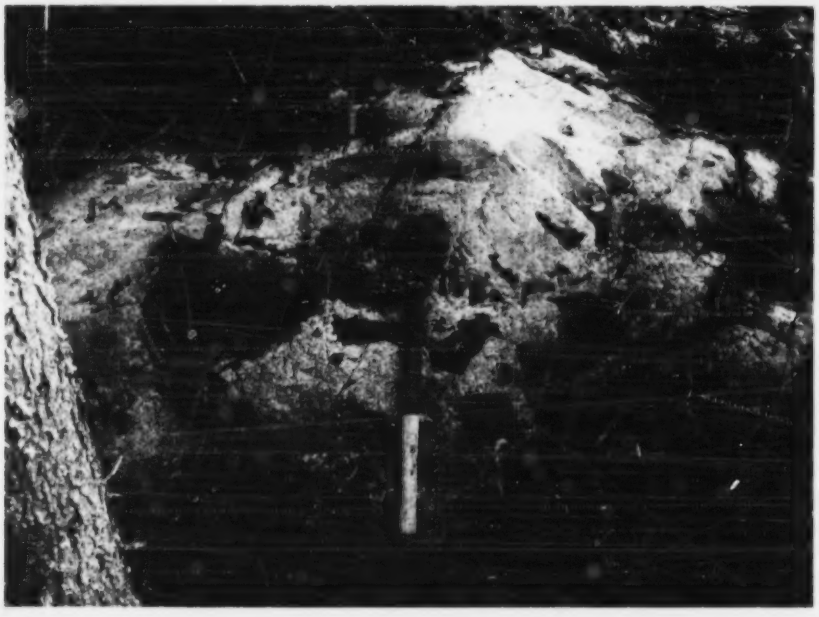

Photo 6. Medium-grained red granite to syenite of the sanukitoid suite intruding an earlier gabbro to diorite phase in the Pillar Lake area. Station 1083; UTM 347400E, 5562944N. Hammer handle is 35 cm long.

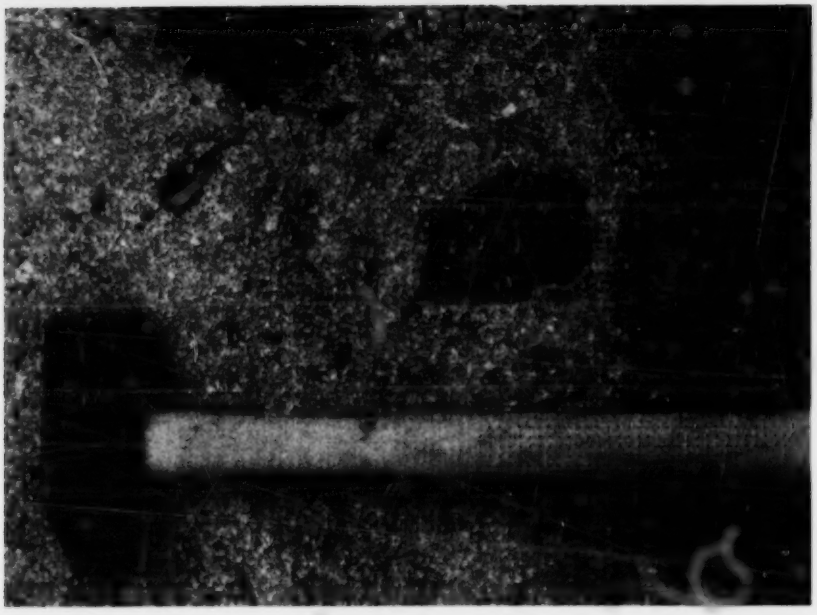

Photo 7. Partially digested, recessive, xenoliths or autoliths of a slightly more mafic (earlier) phase intruded by syenite to monzonite of the sanuitoid suite. East shore of Pillar Lake. Station 1082; UTM 347412E, 5562804N; Zone 16. Hammer handle is 35 cm long.

Photo 8. Diabase dike (possibly Nipigon sill age?) intruding medium-to coarse-grained alkali syenite of the sanukitoid suite, Waweig Lake. Station 1005; UTM 350382E, 5554307N; Zone 16. Pen is 15 cm long.

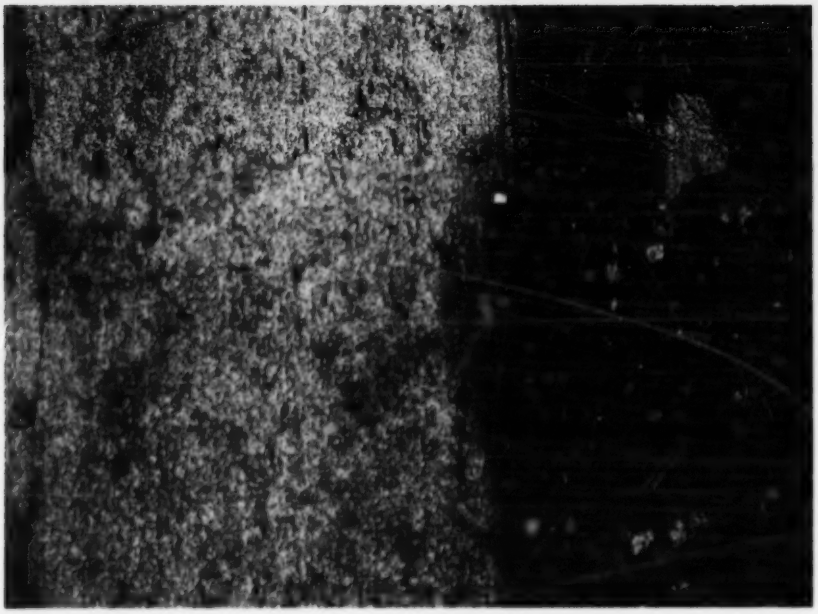

Photo 9. Fragment-rich lamprophyre dike (right) intruded into foliated granitoids and gneisses of the Wabigoon Subprovince. North Shaw Lake area. Station 3012; UTM 354334E, 5543229N; Zone 16. Pen is 15 cm long.

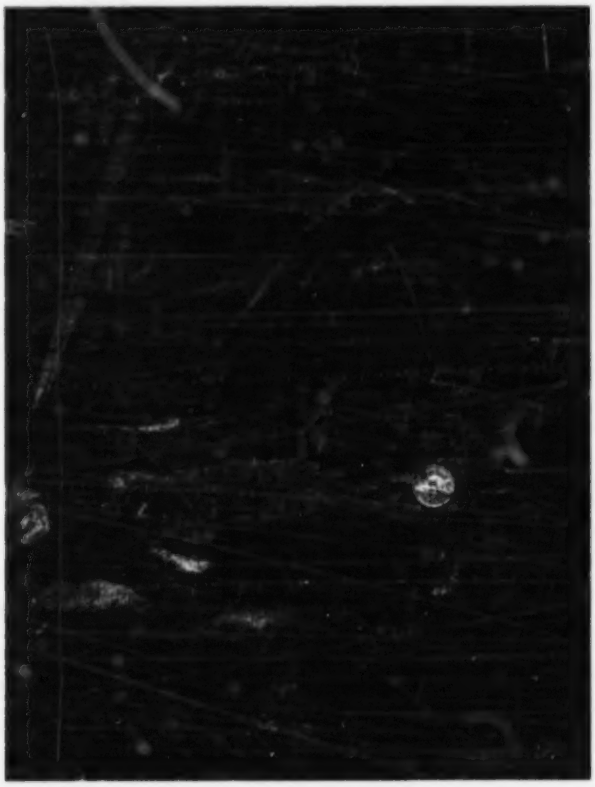

Photo 10. Reddish beds of silty dolostone and silty sandstone of the Sibley Group, Waweig Lake area. Station 2217; UTM 352424E, 5555235N; Zone 16. Coin is 2.1 cm in diameter.

Photo 11. Poorly sorted heterolithic conglomerate, northwest shore of Chimney Lake. Station 2236; UTM 349737E, 5563344N; Zone 16. Knife is 10 cm long.

Photo 12. Pink to white, subrounded quartz-rich fragment in poorly sorted heterolithic conglomerate, Chimney Lake area. Station 2236; UTM 349737E, 5563344N; Zone 16. Knife is 10 cm long.

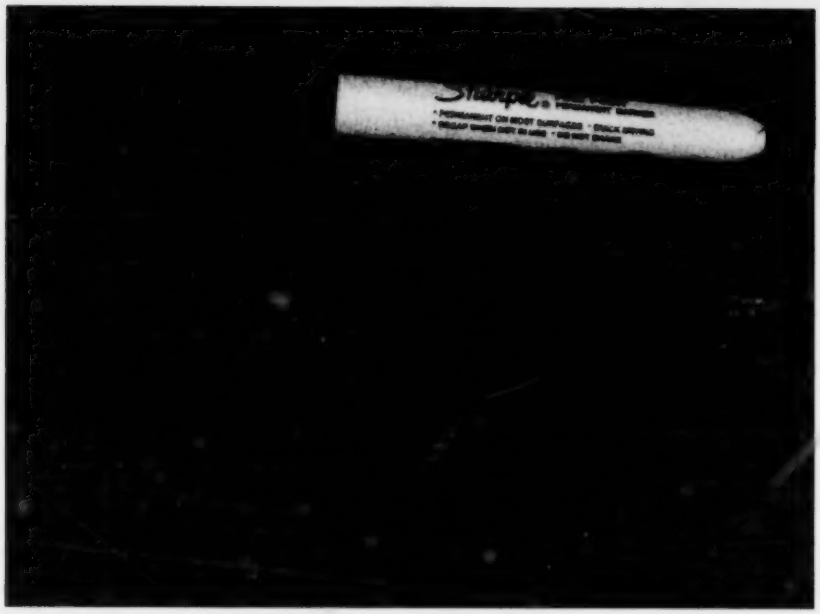

Photo 13. Fine tuff to crystal tuff bed (1-2 cm wide, delineated by white lines) in crystal lapilli tuffs of the English Bay complex. Diamond-drill hole EB-1. Pen is 15 cm long.

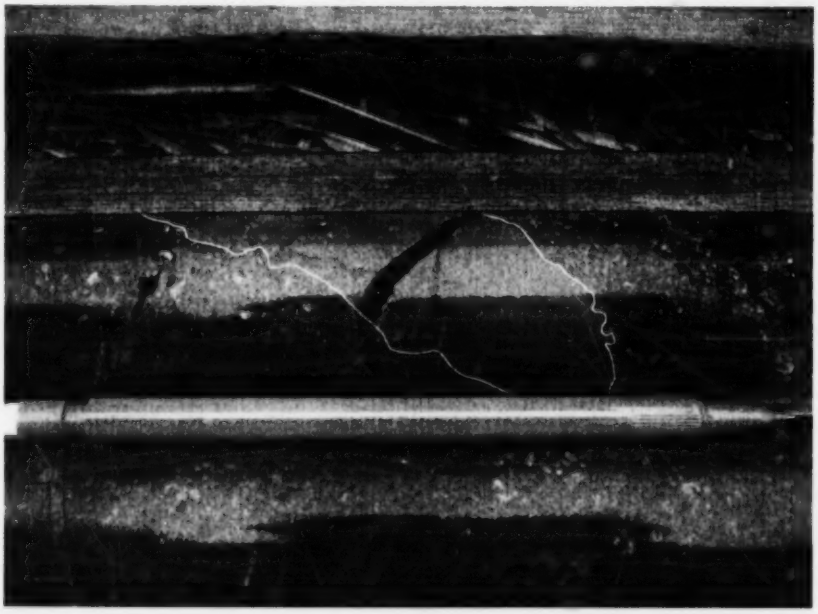

Photo 14. Fine tuff bed or fragment (delineated by white lines) in crystal tuff to crystal lithic lapilli tuff of the English Bay complex. Diamond-drill hole EB-2, 288 m depth. Pen is 15 cm long.

Photo 15. Bedded crystal tuffs of the English Bay complex. South Vooges Lake. Station 1133; UTM 356192E, 5535003N; Zone 16. Pen is 15 cm long.

Photo 16. Recessively weathering pumiceous fragment in quartz feldspar crystal tuff. Station 1122; UTM 366101E, 5535741N; Zone 16. Pen is 15 cm long.

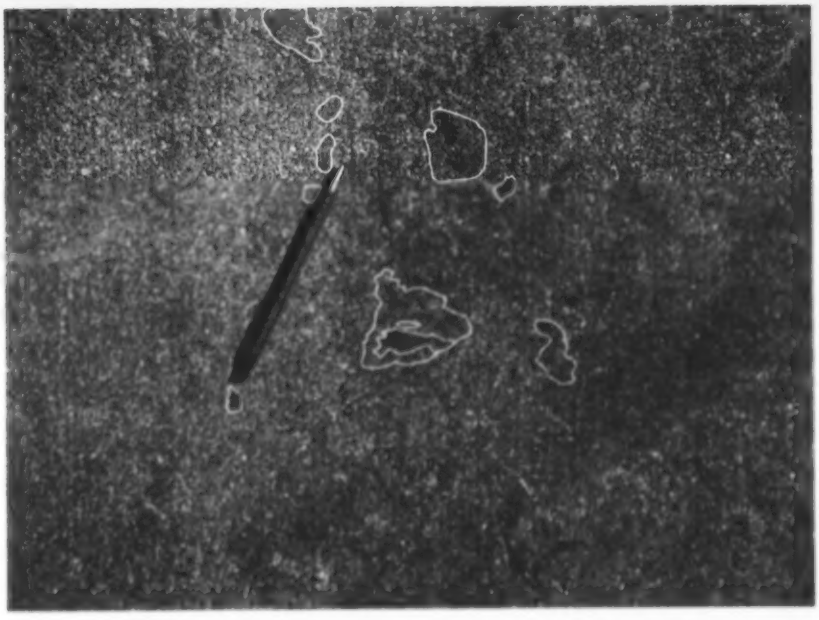

Photo 17. Crystal tuff to crystal lapilli tuff of the English Bay complex. Red aphanitic fine tuff fragments (delineated by white lines) of similar composition to the crystal tuff matrix form the dominant lapilli type at this location. Note the composite lapilli at the center of photo consisting of a long-tubed pumice fragment with ragged margins enclosed by red fine tuff. English Bay area. Station 1122; UTM 366101, 5535741, Zone 16. Pen is 15 cm long.

Photo 18. Crystal tuff to crystal lithic lapilli tuffs of the English Bay complex. Vooges Lake road. Station 3000; UTM 355013, 5534999, Zone 16. Pen is 15 cm long.

Photo 19. Grey to maroon crystal lithic lapilli tuff of the English Bay complex. Note the composite light pink quartz and feldspar crystal phyric lapilli to block sized cognate lithic fragment at the center of photo. The light green rimmed fragment within the light colored lapilli/block is possibly altered pumice or other juvenile material. Station 3000; UTM 355013, 5534999, Zone 16. Pen is 15 cm long.

Photo 20. Crystal lithic lapilli tuff to pyroclastic breccia from diamond drill hole EB-3 at 257 m depth. Note the distinctive "striped" fragments and possible strong silicification and chloritization in addition to hematite alteration. Pen is 15 cm long.

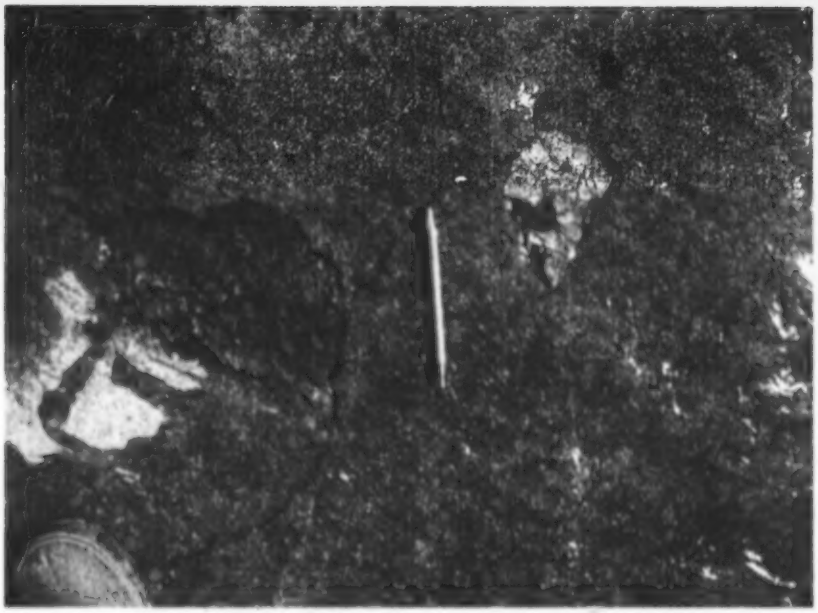

Photo 21. Fine- to very fine-grained quartz-rich fragments in crystal lapilli to crystal lithic lapilli tuffs of the English Bay complex. Island in English Bay. Station 1122; UTM 366101, 5535741, Zone 16. Pen is 15 cm long.

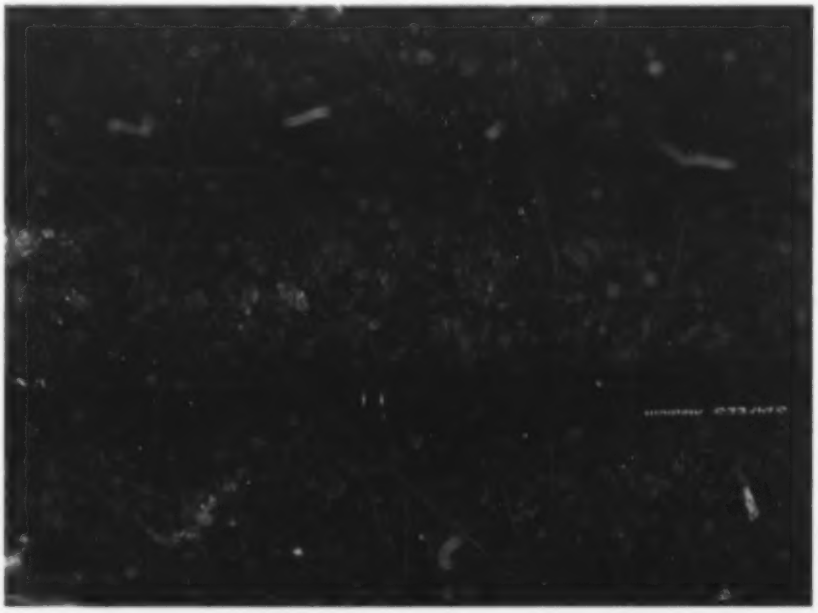

Photo 22. Massive crystal tuff and/or "granitic" intrusive porphyry of the English Bay complex from diamond-drill hole EB-1 at 250 meters depth. Pen is 15 cm long.

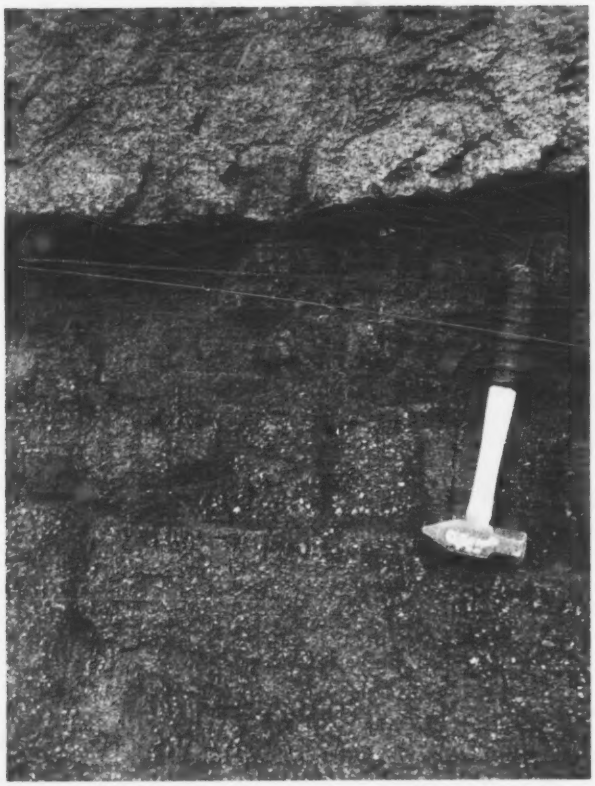

Photo 23. Massive, coarse- to very coarse-grained oikocrystic diabase with prominent horizontal joints. Collins River Road/North Bukemiga Lake area. Station 3099; UTM 339969, 5557949, Zone 16. Hammer is 35 cm long.

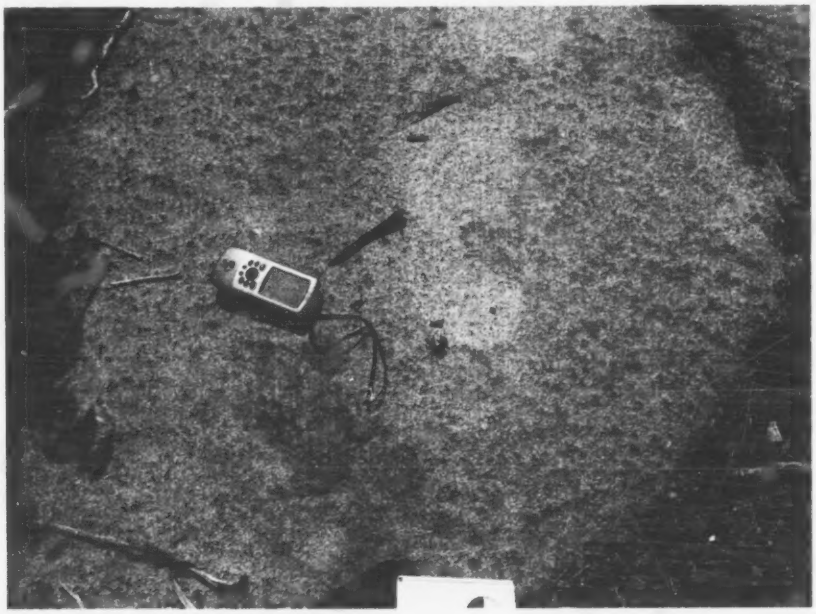

Photo 24. Magnetic porphyritic to glomeroporphyritic (dark spots) in Nipigon diabase. South Wabinosh Lake area. Station 1070; UTM 356062, 5544128, Zone 16. GPS unit is 15 cm long.

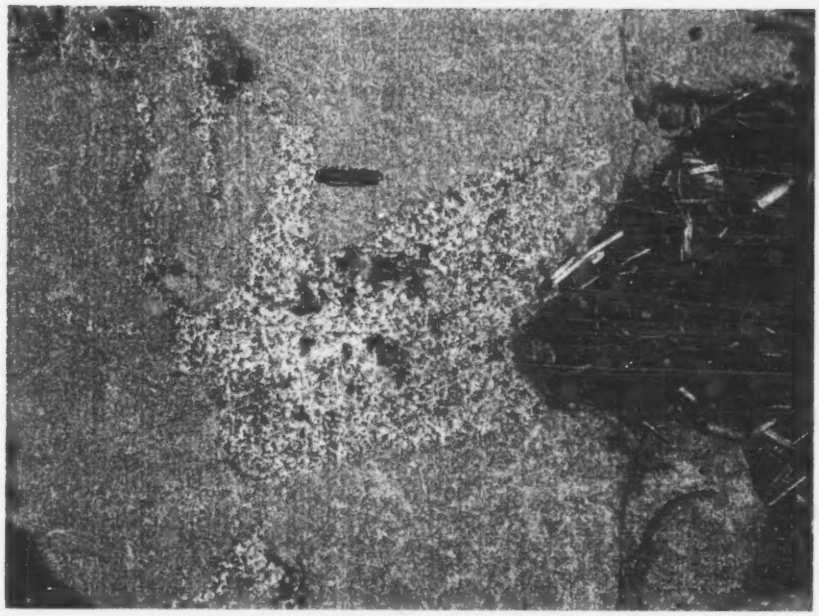

Photo 25. Pegmatitic diabase pods in medium-grained massive diabase. Northwest of Cry Lake. Station 2053; UTM 353497, 5533868, Zone 16. Knife is 10 cm long.

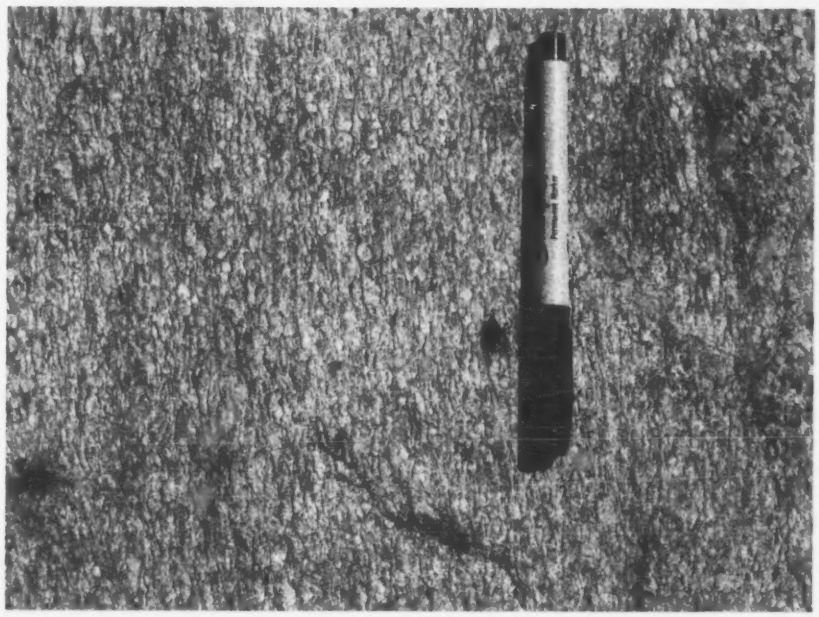

Photo 26. Protomylonitic tonalite to granodiorite. Note the feldspar augen and the ribbon quartz that define the foliation. Station 3002; UTM 355989, 5534178, Zone 16. Pen is 15 cm long.

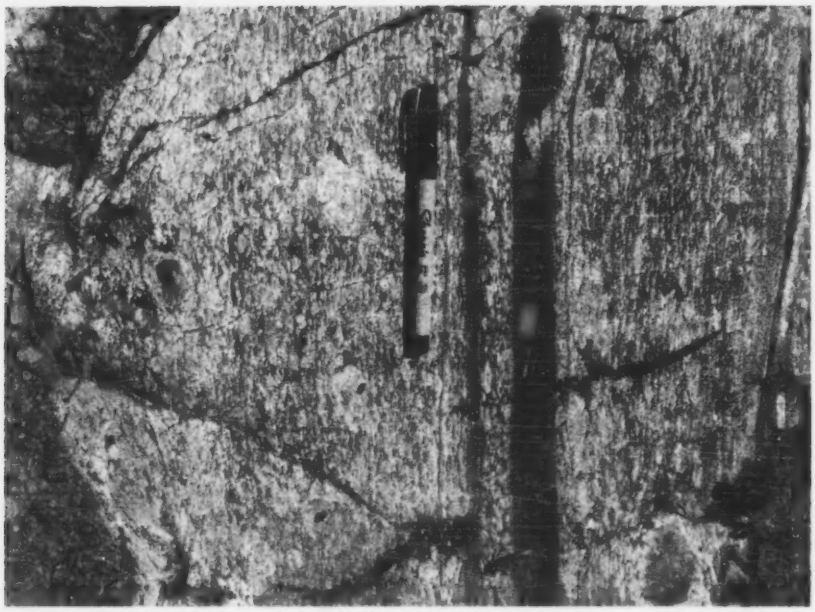

Photo 27. Foliated to protomylonitic outcrops along the Vooges Lake Road. Feldspar megacrysts to augen possibly indicate a dextral sense-of-shear. Station 3002; UTM 355989, 5534178, Zone 16. Pen is 15 cm long.

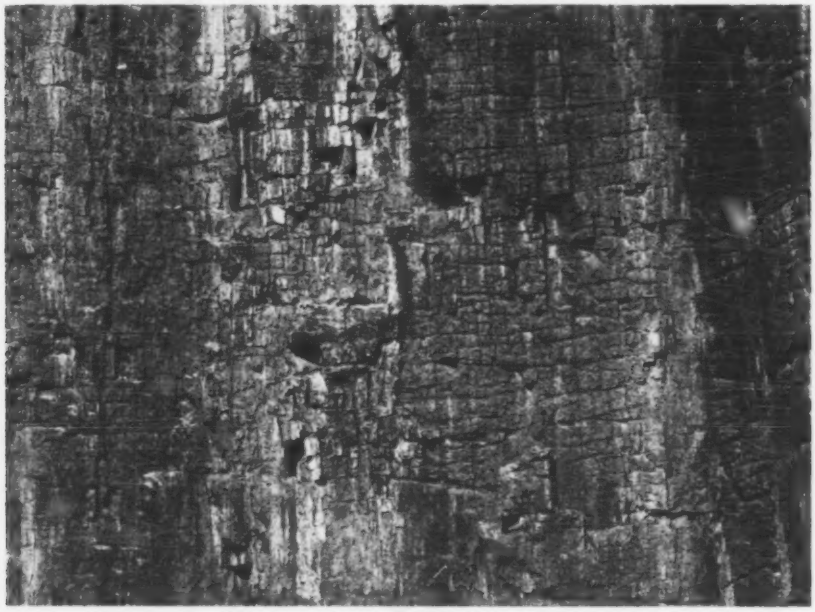

Photo 28. Horizontal and vertical jointing pattern in diabase. Station 3162; UTM 354462E, 5559711N, Zone 16.

Photo 29. Jointing in crystal lapilli tuffs of the English Bay complex. West shore of English Bay. Station 1113; UTM 365743, 5538469, Zone 16. Pen is 15 cm long.

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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